Dry Bean Classification using Deep Learning

By:

Urvashi Dube

Sudhish Subramaniam

Model Structure

Layer(type)	Output Shape	Param #	Connected to
conv1_conv (Conv2D)	(None, 128, 128, 64)	9472	['conv1_pad[0][0]']
conv1_bn (BatchNormalizati	(None, 128, 128, 64)	256	['conv1_conv[0][0]']
conv1_relu (Activation)	(None, 128, 128, 64)	0	['conv1_bn[0][0]']
pool1_pad (ZeroPadding2D)	(None, 130, 130, 64)	0	['conv1_relu[0][0]']
pool1_pool (MaxPooling2D)	(None, 64, 64, 64)	0	['pool1_pad[0][0]']
conv2_block1_1_conv (Conv2	(None, 64, 64, 64)	4160	['pool1_pool[0][0]']
conv2_block1_1_bn (BatchNo	(None, 64, 64, 64)	256	['conv2_block1_1_conv[0][0]']
conv2_block1_1_relu (Activ	(None, 64, 64, 64)	0	['conv2_block1_1_bn[0][0]']
conv2_block1_2_conv (Conv2	(None, 64, 64, 64)	36928	['conv2_block1_1_relu[0][0]']
conv2_block1_2_bn (BatchNo	(None, 64, 64, 64)	256	['conv2_block1_2_conv[0][0]']
conv2_block1_2_relu (Activ	(None, 64, 64, 64)	0	['conv2_block1_2_bn[0][0]']
conv2_block1_0_conv (Conv2	(None, 64, 64, 256)	16640	['pool1_pool[0][0]']
conv2_block1_3_conv (Conv2	(None, 64, 64, 256)	16640	['conv2_block1_2_relu[0][0]']
conv2_block1_0_bn (BatchNo	(None, 64, 64, 256)	1024	['conv2_block1_0_conv[0][0]']
conv2_block1_3_bn (BatchNo	(None, 64, 64, 256)	1024	['conv2_block1_3_conv[0][0]']
conv2_block1_add (Add)	(None, 64, 64, 256)	0	['conv2_block1_0_bn[0][0]',
conv2_block1_out (Activati	(None, 64, 64, 256)	0	['conv2_block1_add[0][0]']
conv2_block2_1_conv (Conv2	(None, 64, 64, 64)	16448	['conv2_block1_out[0][0]']
conv2_block2_1_bn (BatchNo	(None, 64, 64, 64)	256	['conv2_block2_1_conv[0][0]']
conv2_block2_1_relu (Activ	(None, 64, 64, 64)	0	['conv2_block2_1_bn[0][0]']
conv2_block2_2_conv (Conv2	(None, 64, 64, 64)	36928	['conv2_block2_1_relu[0][0]']
conv2_block2_2_bn (BatchNo	(None, 64, 64, 64)	256	['conv2_block2_2_conv[0][0]']
conv2_block2_2_relu (Activ	(None, 64, 64, 64)	0	['conv2_block2_2_bn[0][0]']

|			
conv2_block2_3_conv (Conv2	(None, 64, 64, 256)	16640	['conv2_block2_2_relu[0][0]']
conv2_block2_3_bn (BatchNo	(None, 64, 64, 256)	1024	['conv2_block2_3_conv[0][0]']
conv2_block2_add (Add)	(None, 64, 64, 256)	0	['conv2_block1_out[0][0]',
conv2_block2_out (Activati	(None, 64, 64, 256)	0	['conv2_block2_add[0][0]']
conv2_block3_1_conv (Conv2	(None, 64, 64, 64)	16448	['conv2_block2_out[0][0]']
conv2_block3_1_bn (BatchNo	(None, 64, 64, 64)	256	['conv2_block3_1_conv[0][0]']
conv2_block3_1_relu (Activ	(None, 64, 64, 64)	0	['conv2_block3_1_bn[0][0]']
conv2_block3_2_conv (Conv2	(None, 64, 64, 64)	36928	['conv2_block3_1_relu[0][0]']
conv2_block3_2_bn (BatchNo	(None, 64, 64, 64)	256	['conv2_block3_2_conv[0][0]']
conv2_block3_2_relu (Activ	(None, 64, 64, 64)	0	['conv2_block3_2_bn[0][0]']
conv2_block3_3_conv (Conv2	(None, 64, 64, 256)	16640	['conv2_block3_2_relu[0][0]']
conv2_block3_3_bn (BatchNo	(None, 64, 64, 256)	1024	['conv2_block3_3_conv[0][0]']
conv2_block3_add (Add)	(None, 64, 64, 256)	0	['conv2_block2_out[0][0]',
conv2_block3_out (Activati	(None, 64, 64, 256)	0	['conv2_block3_add[0][0]']
conv3_block1_1_conv (Conv2	(None, 32, 32, 128)	32896	['conv2_block3_out[0][0]']
conv3_block1_1_bn (BatchNo	(None, 32, 32, 128)	512	['conv3_block1_1_conv[0][0]']
conv3_block1_1_relu (Activ	(None, 32, 32, 128)	0	['conv3_block1_1_bn[0][0]']
conv3_block1_2_conv (Conv2	(None, 32, 32, 128)	147584	['conv3_block1_1_relu[0][0]']
conv3_block1_2_bn (BatchNo	(None, 32, 32, 128)	512	['conv3_block1_2_conv[0][0]']
conv3_block1_2_relu (Activ	(None, 32, 32, 128)	0	['conv3_block1_2_bn[0][0]']
conv3_block1_0_conv (Conv2	(None, 32, 32, 512)	131584	['conv2_block3_out[0][0]']
conv3_block1_3_conv (Conv2	(None, 32, 32, 512)	66048	['conv3_block1_2_relu[0][0]']
conv3_block1_0_bn (BatchNo	(None, 32, 32, 512)	2048	['conv3_block1_0_conv[0][0]']
conv3_block1_3_bn (BatchNo	(None, 32, 32, 512)	2048	['conv3_block1_3_conv[0][0]']
conv3_block1_add (Add)	(None, 32, 32, 512)	0	['conv3_block1_0_bn[0][0]',
conv3_block1_out (Activati	(None, 32, 32, 512)	0	['conv3_block1_add[0][0]']
conv3_block2_1_conv (Conv2	(None, 32, 32, 128)	65664	['conv3_block1_out[0][0]']
conv3_block2_1_bn (BatchNo	(None, 32, 32, 128)	512	['conv3_block2_1_conv[0][0]']
conv3_block2_1_relu (Activ	(None, 32, 32, 128)	0	['conv3_block2_1_bn[0][0]']
conv3_block2_2_conv (Conv2	(None, 32, 32, 128)	147584	['conv3_block2_1_relu[0][0]']
conv3_block2_2_bn (BatchNo	(None, 32, 32, 128)	512	['conv3_block2_2_conv[0][0]']
conv3_block2_2_relu (Activ	(None, 32, 32, 128)	0	['conv3_block2_2_bn[0][0]']

conv3_block2_3_conv (Conv2	(None, 32, 32, 512)	66048	['conv3_block2_2_relu[0][0]']
conv3_block2_3_bn (BatchNo	(None, 32, 32, 512)	2048	['conv3_block2_3_conv[0][0]']
conv3_block2_add (Add)	(None, 32, 32, 512)	0	['conv3_block1_out[0][0]',
conv3_block2_out (Activati	(None, 32, 32, 512)	0	['conv3_block2_add[0][0]']
conv3_block3_1_conv (Conv2	(None, 32, 32, 128)	65664	['conv3_block2_out[0][0]']
conv3_block3_1_bn (BatchNo	(None, 32, 32, 128)	512	['conv3_block3_1_conv[0][0]']
conv3_block3_1_relu (Activ	(None, 32, 32, 128)	0	['conv3_block3_1_bn[0][0]']
conv3_block3_2_conv (Conv2	(None, 32, 32, 128)	147584	['conv3_block3_1_relu[0][0]']
conv3_block3_2_bn (BatchNo	(None, 32, 32, 128)	512	['conv3_block3_2_conv[0][0]']
conv3_block3_2_relu (Activ	(None, 32, 32, 128)	0	['conv3_block3_2_bn[0][0]']
conv3_block3_3_conv (Conv2	(None, 32, 32, 512)	66048	['conv3_block3_2_relu[0][0]']
conv3_block3_3_bn (BatchNo	(None, 32, 32, 512)	2048	['conv3_block3_3_conv[0][0]']
conv3_block3_add (Add)	(None, 32, 32, 512)	0	['conv3_block2_out[0][0]',
conv3_block3_out (Activati	(None, 32, 32, 512)	0	['conv3_block3_add[0][0]']
conv3_block4_1_conv (Conv2	(None, 32, 32, 128)	65664	['conv3_block3_out[0][0]']
conv3_block4_1_bn (BatchNo	(None, 32, 32, 128)	512	['conv3_block4_1_conv[0][0]']
conv3_block4_1_relu (Activ	(None, 32, 32, 128)	0	['conv3_block4_1_bn[0][0]']
conv3_block4_2_conv (Conv2	(None, 32, 32, 128)	147584	['conv3_block4_1_relu[0][0]']
conv3_block4_2_bn (BatchNo	(None, 32, 32, 128)	512	['conv3_block4_2_conv[0][0]']
conv3_block4_2_relu (Activ	(None, 32, 32, 128)	0	['conv3_block4_2_bn[0][0]']
conv3_block4_3_conv (Conv2	(None, 32, 32, 512)	66048	['conv3_block4_2_relu[0][0]']
conv3_block4_3_bn (BatchNo	(None, 32, 32, 512)	2048	['conv3_block4_3_conv[0][0]']
conv3_block4_add (Add)	(None, 32, 32, 512)	0	['conv3_block3_out[0][0]',
conv3_block4_out (Activati	(None, 32, 32, 512)	0	['conv3_block4_add[0][0]']
conv4_block1_1_conv (Conv2	(None, 16, 16, 256)	131328	['conv3_block4_out[0][0]']
conv4_block1_1_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block1_1_conv[0][0]']
conv4_block1_1_relu (Activ	(None, 16, 16, 256)	0	['conv4_block1_1_bn[0][0]']
conv4_block1_2_conv (Conv2	(None, 16, 16, 256)	590080	['conv4_block1_1_relu[0][0]']
conv4_block1_2_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block1_2_conv[0][0]']
conv4_block1_2_relu (Activ	(None, 16, 16, 256)	0	['conv4_block1_2_bn[0][0]']
conv4_block1_0_conv (Conv2	(None, 16, 16, 1024)	525312	['conv3_block4_out[0][0]']
conv4_block1_3_conv (Conv2	(None, 16, 16, 1024)	263168	['conv4_block1_2_relu[0][0]']

|			
conv4_block1_0_bn (BatchNo	(None, 16, 16, 1024)	4096	['conv4_block1_0_conv[0][0]']
conv4_block1_3_bn (BatchNo	(None, 16, 16, 1024)	4096	['conv4_block1_3_conv[0][0]']
conv4_block1_add (Add)	(None, 16, 16, 1024)	0	['conv4_block1_0_bn[0][0]',
conv4_block1_out (Activati	(None, 16, 16, 1024)	0	['conv4_block1_add[0][0]']
conv4_block2_1_conv (Conv2	(None, 16, 16, 256)	262400	['conv4_block1_out[0][0]']
conv4_block2_1_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block2_1_conv[0][0]']
conv4_block2_1_relu (Activ	(None, 16, 16, 256)	0	['conv4_block2_1_bn[0][0]']
conv4_block2_2_conv (Conv2	(None, 16, 16, 256)	590080	['conv4_block2_1_relu[0][0]']
conv4_block2_2_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block2_2_conv[0][0]']
conv4_block2_2_relu (Activ	(None, 16, 16, 256)	0	['conv4_block2_2_bn[0][0]']
conv4_block2_3_conv (Conv2	(None, 16, 16, 1024)	263168	['conv4_block2_2_relu[0][0]']
conv4_block2_3_bn (BatchNo	(None, 16, 16, 1024)	4096	['conv4_block2_3_conv[0][0]']
conv4_block2_add (Add)	(None, 16, 16, 1024)	0	['conv4_block1_out[0][0]',
conv4_block2_out (Activati	(None, 16, 16, 1024)	0	['conv4_block2_add[0][0]']
conv4_block3_1_conv (Conv2	(None, 16, 16, 256)	262400	['conv4_block2_out[0][0]']
conv4_block3_1_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block3_1_conv[0][0]']
conv4_block3_1_relu (Activ	(None, 16, 16, 256)	0	['conv4_block3_1_bn[0][0]']
conv4_block3_2_conv (Conv2	(None, 16, 16, 256)	590080	['conv4_block3_1_relu[0][0]']
conv4_block3_2_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block3_2_conv[0][0]']
conv4_block3_2_relu (Activ	(None, 16, 16, 256)	0	['conv4_block3_2_bn[0][0]']
conv4_block3_3_conv (Conv2	(None, 16, 16, 1024)	263168	['conv4_block3_2_relu[0][0]']
conv4_block3_3_bn (BatchNo	(None, 16, 16, 1024)	4096	['conv4_block3_3_conv[0][0]']
conv4_block3_add (Add)	(None, 16, 16, 1024)	0	['conv4_block2_out[0][0]',
conv4_block3_out (Activati	(None, 16, 16, 1024)	0	['conv4_block3_add[0][0]']
conv4_block4_1_conv (Conv2	(None, 16, 16, 256)	262400	['conv4_block3_out[0][0]']
conv4_block4_1_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block4_1_conv[0][0]']
conv4_block4_1_relu (Activ	(None, 16, 16, 256)	0	['conv4_block4_1_bn[0][0]']
conv4_block4_2_conv (Conv2	(None, 16, 16, 256)	590080	['conv4_block4_1_relu[0][0]']
conv4_block4_2_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block4_2_conv[0][0]']

conv4_block4_2_relu (Activ	(None, 16, 16, 256)	0	['conv4_block4_2_bn[0][0]']
conv4_block4_3_conv (Conv2	(None, 16, 16, 1024)	263168	['conv4_block4_2_relu[0][0]']
conv4_block4_3_bn (BatchNo	(None, 16, 16, 1024)	4096	['conv4_block4_3_conv[0][0]']
conv4_block4_add (Add)	(None, 16, 16, 1024)	0	['conv4_block3_out[0][0]',
conv4_block4_out (Activati	(None, 16, 16, 1024)	0	['conv4_block4_add[0][0]']
conv4_block5_1_conv (Conv2	(None, 16, 16, 256)	262400	['conv4_block4_out[0][0]']
conv4_block5_1_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block5_1_conv[0][0]']
conv4_block5_1_relu (Activ	(None, 16, 16, 256)	0	['conv4_block5_1_bn[0][0]']
conv4_block5_2_conv (Conv2	(None, 16, 16, 256)	590080	['conv4_block5_1_relu[0][0]']
conv4_block5_2_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block5_2_conv[0][0]']
conv4_block5_2_relu (Activ	(None, 16, 16, 256)	0	['conv4_block5_2_bn[0][0]']
conv4_block5_3_conv (Conv2	(None, 16, 16, 1024)	263168	['conv4_block5_2_relu[0][0]']
conv4_block5_3_bn (BatchNo	(None, 16, 16, 1024)	4096	['conv4_block5_3_conv[0][0]']
conv4_block5_add (Add)	(None, 16, 16, 1024)	0	['conv4_block4_out[0][0]',
conv4_block5_out (Activati	(None, 16, 16, 1024)	0	['conv4_block5_add[0][0]']
conv4_block6_1_conv (Conv2	(None, 16, 16, 256)	262400	['conv4_block5_out[0][0]']
conv4_block6_1_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block6_1_conv[0][0]']
conv4_block6_1_relu (Activ	(None, 16, 16, 256)	0	['conv4_block6_1_bn[0][0]']
conv4_block6_2_conv (Conv2	(None, 16, 16, 256)	590080	['conv4_block6_1_relu[0][0]']
conv4_block6_2_bn (BatchNo	(None, 16, 16, 256)	1024	['conv4_block6_2_conv[0][0]']
conv4_block6_2_relu (Activ	(None, 16, 16, 256)	0	['conv4_block6_2_bn[0][0]']
conv4_block6_3_conv (Conv2	(None, 16, 16, 1024)	263168	['conv4_block6_2_relu[0][0]']
conv4_block6_3_bn (BatchNo	(None, 16, 16, 1024)	4096	['conv4_block6_3_conv[0][0]']
conv4_block6_add (Add)	(None, 16, 16, 1024)	0	['conv4_block5_out[0][0]',
conv4_block6_out (Activati	(None, 16, 16, 1024)	0	['conv4_block6_add[0][0]']
conv5_block1_1_conv (Conv2	(None, 8, 8, 512)	524800	['conv4_block6_out[0][0]']
conv5_block1_1_bn (BatchNo	(None, 8, 8, 512)	2048	['conv5_block1_1_conv[0][0]']
conv5_block1_1_relu (Activ	(None, 8, 8, 512)	0	['conv5_block1_1_bn[0][0]']
conv5_block1_2_conv (Conv2	(None, 8, 8, 512)	2359808	['conv5_block1_1_relu[0][0]']

conv5_block1_2_bn (BatchNo	(None, 8, 8, 512)	2048	['conv5_block1_2_conv[0][0]']
conv5_block1_2_relu (Activ	(None, 8, 8, 512)	0	['conv5_block1_2_bn[0][0]']
conv5_block1_0_conv (Conv2	(None, 8, 8, 2048)	2099200	['conv4_block6_out[0][0]']
conv5_block1_3_conv (Conv2	(None, 8, 8, 2048)	1050624	['conv5_block1_2_relu[0][0]']
conv5_block1_0_bn (BatchNo	(None, 8, 8, 2048)	8192	['conv5_block1_0_conv[0][0]']
conv5_block1_3_bn (BatchNo	(None, 8, 8, 2048)	8192	['conv5_block1_3_conv[0][0]']
conv5_block1_add (Add)	(None, 8, 8, 2048)	0	['conv5_block1_0_bn[0][0]',
conv5_block1_out (Activati	(None, 8, 8, 2048)	0	['conv5_block1_add[0][0]']
conv5_block2_1_conv (Conv2	(None, 8, 8, 512)	1049088	['conv5_block1_out[0][0]']
conv5_block2_1_bn (BatchNo	(None, 8, 8, 512)	2048	['conv5_block2_1_conv[0][0]']
conv5_block2_1_relu (Activ	(None, 8, 8, 512)	0	['conv5_block2_1_bn[0][0]']
conv5_block2_2_conv (Conv2	(None, 8, 8, 512)	2359808	['conv5_block2_1_relu[0][0]']
conv5_block2_2_bn (BatchNo	(None, 8, 8, 512)	2048	['conv5_block2_2_conv[0][0]']
conv5_block2_2_relu (Activ	(None, 8, 8, 512)	0	['conv5_block2_2_bn[0][0]']
conv5_block2_3_conv (Conv2	(None, 8, 8, 2048)	1050624	['conv5_block2_2_relu[0][0]']
conv5_block2_3_bn (BatchNo	(None, 8, 8, 2048)	8192	['conv5_block2_3_conv[0][0]']
conv5_block2_add (Add)	(None, 8, 8, 2048)	0	['conv5_block1_out[0][0]',
conv5_block2_out (Activati	(None, 8, 8, 2048)	0	['conv5_block2_add[0][0]']
conv5_block3_1_conv (Conv2	(None, 8, 8, 512)	1049088	['conv5_block2_out[0][0]']
conv5_block3_1_bn (BatchNo	(None, 8, 8, 512)	2048	['conv5_block3_1_conv[0][0]']
conv5_block3_1_relu (Activ	(None, 8, 8, 512)	0	['conv5_block3_1_bn[0][0]']
conv5_block3_2_conv (Conv2	(None, 8, 8, 512)	2359808	['conv5_block3_1_relu[0][0]']
conv5_block3_2_bn (BatchNo	(None, 8, 8, 512)	2048	['conv5_block3_2_conv[0][0]']
conv5_block3_2_relu (Activ	(None, 8, 8, 512)	0	['conv5_block3_2_bn[0][0]']
conv5_block3_3_conv (Conv2	(None, 8, 8, 2048)	1050624	['conv5_block3_2_relu[0][0]']
conv5_block3_3_bn (BatchNo	(None, 8, 8, 2048)	8192	['conv5_block3_3_conv[0][0]']
conv5_block3_add (Add)	(None, 8, 8, 2048)	0	['conv5_block2_out[0][0]',
conv5_block3_out (Activati	(None, 8, 8, 2048)	0	['conv5_block3_add[0][0]']
flatten_3 (Flatten)	(None, 131072)	0	['conv5_block3_out[0][0]']
dense_9 (Dense)	(None, 256)	3355468	['flatten_3[0][0]']
batch_normalization_6 (Bat	(None, 256)	1024	['dense_9[0][0]']
dense_11 (Dense)	(None, 14)	3598	['batch_normalization_6[0][0]'

Confusion Matrix:

Confusion Matrix
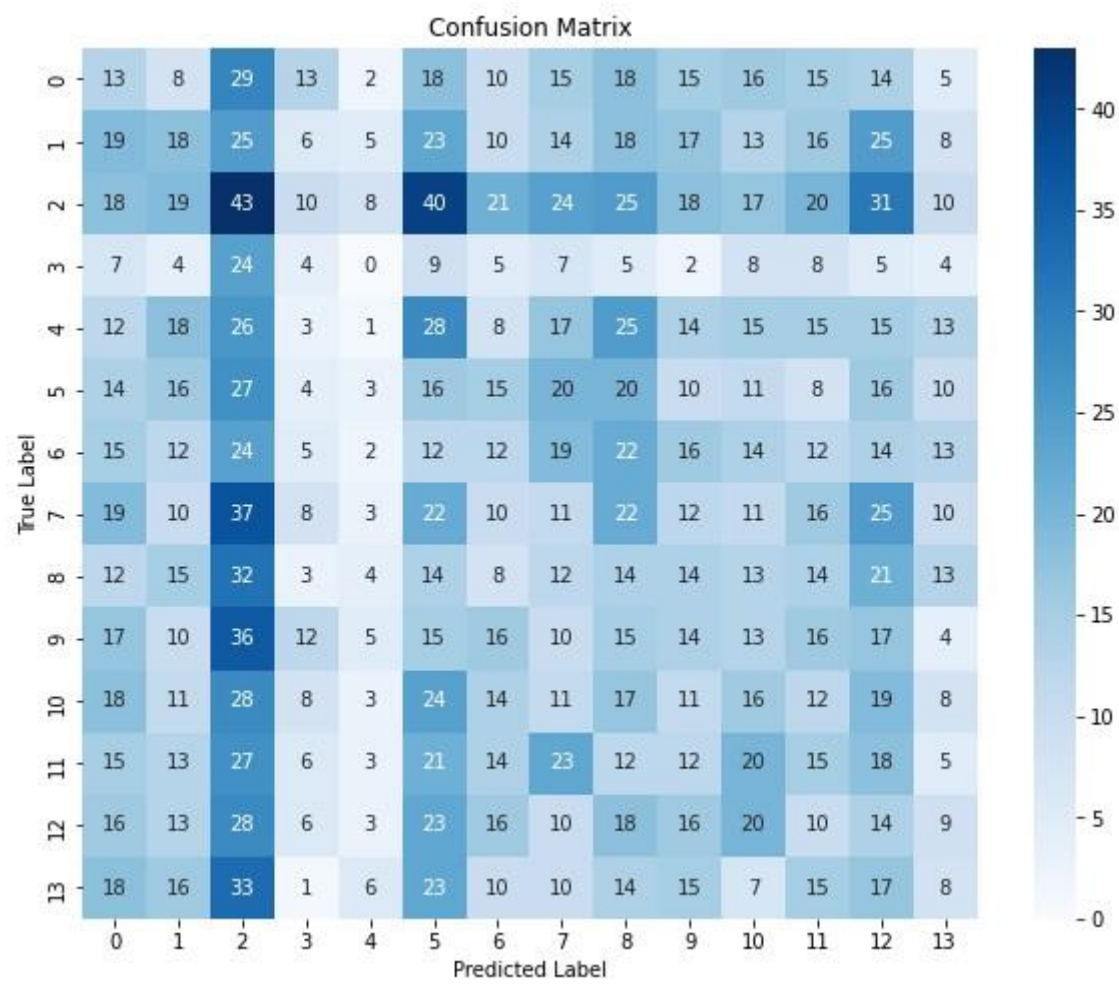
Graph of Mean_Squared_Error_vs_Iteration

Mean Squared Error vs. Iteration
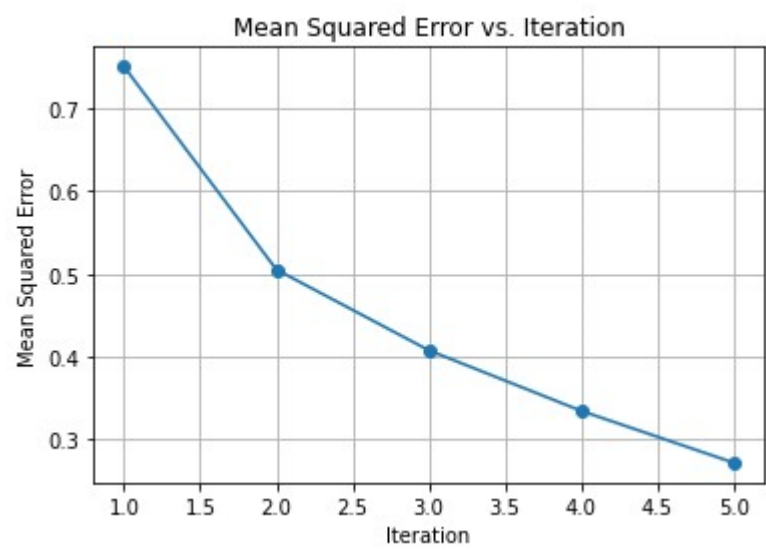
Output of Models

Models run with only 5 epochs

VGG16

```
Epoch 1/5
20/20 [==============================] - 619s 32s/step - loss: 9.3453 - accuracy: 0.3281 - val_loss: 10.7714
- val_accuracy: 0.3446
Epoch 2/5
20/20 [==============================] - 561s 29s/step - loss: 4.3065 - accuracy: 0.5422 - val_loss: 11.5287
- val_accuracy: 0.3725
Epoch 3/5
20/20 [==============================] - 404s 21s/step - loss: 3.6816 - accuracy: 0.6000 - val_loss: 12.6977
- val_accuracy: 0.3611
Epoch 4/5
20/20 [==============================] - 411s 21s/step - loss: 3.5258 - accuracy: 0.6172 - val_loss: 17.4063
- val_accuracy: 0.3264
Epoch 5/5
20/20 [==============================] - 397s 21s/step - loss: 3.6762 - accuracy: 0.6125 - val_loss: 19.1883
- val_accuracy: 0.3171
```

VGG19

```
Epoch 1/5
20/20 [==============================] - 482s 25s/step - loss: 7.7009 - accuracy: 0.3562 - val_loss: 10.9270
- val_accuracy: 0.3811
Epoch 2/5
20/20 [==============================] - 508s 26s/step - loss: 4.2309 - accuracy: 0.5281 - val_loss: 12.4517
- val_accuracy: 0.3604
Epoch 3/5
20/20 [==============================] - 502s 26s/step - loss: 3.2430 - accuracy: 0.5906 - val_loss: 17.0386
- val_accuracy: 0.2771
Epoch 4/5
20/20 [==============================] - 505s 26s/step - loss: 3.8728 - accuracy: 0.6219 - val_loss: 17.9793
- val_accuracy: 0.3357
Epoch 5/5
20/20 [==============================] - 486s 25s/step - loss: 4.0477 - accuracy: 0.5875 - val_loss: 19.3391
- val_accuracy: 0.3489
```

Xception

```
Epoch 1/5
20/20 [==============================] - 179s 9s/step - loss: 10.5659 - accuracy: 0.2516 - val_loss: 159.4602 -
val_accuracy: 0.1368
Epoch 2/5
20/20 [==============================] - 169s 9s/step - loss: 4.9149 - accuracy: 0.4906 - val_loss: 236.4492 -
val_accuracy: 0.0582
Epoch 3/5
20/20 [==============================] - 170s 9s/step - loss: 3.8067 - accuracy: 0.5203 - val_loss: 298.8670 -
val_accuracy: 0.1114
Epoch 4/5
20/20 [==============================] - 172s 9s/step - loss: 2.9978 - accuracy: 0.6016 - val_loss: 344.2356 -
val_accuracy: 0.0836
Epoch 5/5
20/20 [==============================] - 174s 9s/step - loss: 2.8878 - accuracy: 0.5734 - val_loss: 240.5943 -
val_accuracy: 0.0893
```

Model 2 (Without Pretrained Weights)

```
Epoch 1/5
20/20 [==============================] - 600s 31s/
step - loss: 1.8681 - accuracy: 0.3578 - val_loss:
768.5671 - val_accuracy: 0.1489
Epoch 2/5
20/20 [==============================] - 594s 31s/
step - loss: 1.4290 - accuracy: 0.4656 - val_loss:
469.8567 - val_accuracy: 0.1332
Epoch 3/5
20/20 [==============================] - 591s 30s/
step - loss: 1.3613 - accuracy: 0.4656 - val_loss:
11.6613 - val_accuracy: 0.1611
Epoch 4/5
20/20 [==============================] - 583s 30s/
step - loss: 1.2533 - accuracy: 0.5234 - val_loss:
15.0466 - val_accuracy: 0.1611
Epoch 5/5
20/20 [==============================] - 583s 30s/
step - loss: 1.2347 - accuracy: 0.5156 - val_loss:
746.5074 - val_accuracy: 0.1275
C:
```

Models run 5 epochs and 350 steps per epoch

Xception

```
Epoch 1/5
350/350 [==============================] - 3420s 10s/step - loss: 66.6412 - accuracy: 0.4700 - val_loss: 45.3822
- val_accuracy: 0.5318
Epoch 2/5
350/350 [==============================] - 3803s 11s/step - loss: 50.5518 - accuracy: 0.5615 - val_loss: 40.7013
- val_accuracy: 0.6004
Epoch 3/5
350/350 [==============================] - 3768s 11s/step - loss: 43.8055 - accuracy: 0.6073 - val_loss: 38.5669
- val_accuracy: 0.6361
Epoch 4/5
350/350 [==============================] - 3778s 11s/step - loss: 46.6056 - accuracy: 0.6277 - val_loss: 64.2925
- val_accuracy: 0.6021
Epoch 5/5
350/350 [==============================] - 3405s 10s/step - loss: 45.3088 - accuracy: 0.6418 - val_loss: 63.7340
- val_accuracy: 0.6171
```

```
==========================================
Total params: 22696502 (86.58 MB)
Trainable params: 1835022 (7.00 MB)
Non-trainable params: 20861480 (79.58 MB)
```

VGG-19

```
=================================================================
Total params: 20483150 (78.14 MB)
Trainable params: 458766 (1.75 MB)
Non-trainable params: 20024384 (76.39 MB)

Epoch 1/5
350/350 [==============================] - 9531s 27s/step - loss: 5.5898 - accuracy: 0.6217 - val_loss: 4.3095 -
val_accuracy: 0.7054
Epoch 2/5
350/350 [==============================] - 9088s 26s/step - loss: 3.6988 - accuracy: 0.7362 - val_loss: 4.8504 -
val_accuracy: 0.7129
Epoch 3/5
350/350 [==============================] - 4003s 11s/step - loss: 3.0173 - accuracy: 0.7856 - val_loss: 5.1628 -
val_accuracy: 0.7189
Epoch 4/5
350/350 [==============================] - 3482s 10s/step - loss: 2.6500 - accuracy: 0.8122 - val_loss: 5.3075 -
val_accuracy: 0.7364
Epoch 5/5
350/350 [==============================] - 3477s 10s/step - loss: 1.7009 - accuracy: 0.8602 - val_loss: 4.6674 -
val_accuracy: 0.7521
```

Resnet50

```
=================================================================
Total params: 24643982 (94.01 MB)
Trainable params: 1056270 (4.03 MB)
Non-trainable params: 23587712 (89.98 MB)

Epoch 1/5
350/350 [==============================] - 4042s 11s/step - loss: 0.9004 - accuracy: 0.6765 - val_loss: 0.6735 -
val_accuracy: 0.7436
Epoch 2/5
350/350 [==============================] - 3852s 11s/step - loss: 0.6598 - accuracy: 0.7556 - val_loss: 0.7061 -
val_accuracy: 0.7371
Epoch 3/5
350/350 [==============================] - 3867s 11s/step - loss: 0.5961 - accuracy: 0.7772 - val_loss: 0.7001 -
val_accuracy: 0.7332
Epoch 4/5
350/350 [==============================] - 3832s 11s/step - loss: 0.5637 - accuracy: 0.7895 - val_loss: 0.5629 -
val_accuracy: 0.7850
Epoch 5/5
350/350 [==============================] - 3001s 9s/step - loss: 0.5298 - accuracy: 0.8016 - val_loss: 0.5958 -
val_accuracy: 0.7775
```

Model 2 (Without Pretrained Weights)

```
=======================================================
Total params: 23139790 (88.27 MB)
Trainable params: 23139022 (88.27 MB)
Non-trainable params: 768 (3.00 KB)
_____

Epoch 1/5
350/350 [==============================] - 20764s 59s/step - loss: 1.2517 - accuracy: 0.5205 - val_loss:
12056.9375 - val_accuracy: 0.1871
Epoch 2/5
350/350 [==============================] - 8546s 24s/step - loss: 0.9563 - accuracy: 0.6221 - val_loss:
4511378.0000 - val_accuracy: 0.3243
Epoch 3/5
350/350 [==============================] - 5628s 16s/step - loss: 0.8934 - accuracy: 0.6477 - val_loss:
86169944.0000 - val_accuracy: 0.2539
Epoch 4/5
350/350 [==============================] - 5877s 17s/step - loss: 0.8502 - accuracy: 0.6624 - val_loss:
399260512.0000 - val_accuracy: 0.2164
Epoch 5/5
350/350 [==============================] - 5532s 16s/step - loss: 0.8156 - accuracy: 0.6731 - val_loss:
275878656.0000 - val_accuracy: 0.6111
C:\Users\urvas\AppData\Local\Temp\ipykernel_26316\1474647562.py:135: UserWarning: You are saving your model as
an HDF5 file via `model.save()`. This file format is considered legacy. We recommend using instead the native
Keras format, e.g. `model.save('my_model.keras')`.
  save_model(model, 'C:/Users/urvas/Projects/Dry Beans Classification Projects/Programs Used/Models/
My_Model_2.h5')
```

VGG 16

```
=======================================================
Total params: 15173454 (57.88 MB)
Trainable params: 458766 (1.75 MB)
Non-trainable params: 14714688 (56.13 MB)
_____

Epoch 1/5
350/350 [==============================] - 1725s 5s/step - loss: 5.6510 - accuracy: 0.6266 - val_loss: 4.2695 - val_accuracy:
0.7229
Epoch 2/5
350/350 [==============================] - 1768s 5s/step - loss: 3.6523 - accuracy: 0.7511 - val_loss: 6.2727 - val_accuracy:
0.6439
Epoch 3/5
350/350 [==============================] - 1707s 5s/step - loss: 3.4120 - accuracy: 0.7805 - val_loss: 7.1379 - val_accuracy:
0.6854
Epoch 4/5
350/350 [==============================] - 1623s 5s/step - loss: 2.4964 - accuracy: 0.8234 - val_loss: 5.7875 - val_accuracy:
0.7282
Epoch 5/5
350/350 [==============================] - 1555s 4s/step - loss: 2.4253 - accuracy: 0.8305 - val_loss: 5.7005 - val_accuracy:
0.7439
```

Own Model (VGG16 Weights + Flatten + Dense + BatchNorm + Dense + BatchNorm + Dense)

```
=======================================================
Total params: 23139790 (88.27 MB)
Trainable params: 8424334 (32.14 MB)
Non-trainable params: 14715456 (56.14 MB)
_____

Epoch 1/5
350/350 [==============================] - 1544s 4s/step - loss: 0.8084 - accuracy: 0.7151 - val_loss: 0.9371 -
val_accuracy: 0.6800
Epoch 2/5
350/350 [==============================] - 1554s 4s/step - loss: 0.5315 - accuracy: 0.8054 - val_loss: 0.6595 -
val_accuracy: 0.7607
Epoch 3/5
350/350 [==============================] - 1617s 5s/step - loss: 0.4483 - accuracy: 0.8330 - val_loss: 0.6172 -
val_accuracy: 0.7743
Epoch 4/5
350/350 [==============================] - 1600s 5s/step - loss: 0.3824 - accuracy: 0.8599 - val_loss: 0.5762 -
val_accuracy: 0.7896
Epoch 5/5
350/350 [==============================] - 1578s 5s/step - loss: 0.3208 - accuracy: 0.8830 - val_loss: 0.6276 -
val_accuracy: 0.7800
```

Model 3 (Inception Weights)

```
====================================================================================
Total params: 40713646 (155.31 MB)
Trainable params: 18910094 (72.14 MB)
Non-trainable params: 21803552 (83.17 MB)
_____
Epoch 1/5
350/350 [==============================] - 414s 1s/step - loss: 1.0243 - accuracy: 0.6187 - val_loss: 0.9880 - val_accuracy:
0.6361
Epoch 2/5
350/350 [==============================] - 421s 1s/step - loss: 0.7858 - accuracy: 0.6957 - val_loss: 0.7768 - val_accuracy:
0.6943
Epoch 3/5
350/350 [==============================] - 425s 1s/step - loss: 0.7250 - accuracy: 0.7177 - val_loss: 0.7922 - val_accuracy:
0.7011
Epoch 4/5
350/350 [==============================] - 422s 1s/step - loss: 0.6684 - accuracy: 0.7429 - val_loss: 0.7826 - val_accuracy:
0.6925
Epoch 5/5
350/350 [==============================] - 422s 1s/step - loss: 0.6341 - accuracy: 0.7529 - val_loss: 0.7478 - val_accuracy:
0.7139
Out[3]: <keras.src.callbacks.History at 0x1e5482d1a00>
```

Model 4 (Resnet50 Weights)

```
====================================================================================
Total params: 57147022 (218.00 MB)
Trainable params: 33558798 (128.02 MB)
Non-trainable params: 23588224 (89.98 MB)
_____
Epoch 1/5
350/350 [==============================] - 786s 2s/step - loss: 0.7517 - accuracy: 0.7338 - val_loss: 0.6885 -
val_accuracy: 0.7457
Epoch 2/5
350/350 [==============================] - 850s 2s/step - loss: 0.5034 - accuracy: 0.8163 - val_loss: 0.5686 -
val_accuracy: 0.7989
Epoch 3/5
350/350 [==============================] - 846s 2s/step - loss: 0.4047 - accuracy: 0.8518 - val_loss: 0.5787 -
val_accuracy: 0.7964
Epoch 4/5
350/350 [==============================] - 786s 2s/step - loss: 0.3244 - accuracy: 0.8829 - val_loss: 0.6668 -
val_accuracy: 0.7821
Epoch 5/5
350/350 [==============================] - 891s 3s/step - loss: 0.2653 - accuracy: 0.9079 - val_loss: 0.6453 -
val_accuracy: 0.7929
C:\Users\urvas\AppData\Local\Temp\ipykernel_6292\1921603258.py:117: UserWarning: You are saving your model as an HDF5 file
via `model.save()`. This file format is considered legacy. We recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')`.
  save_model(model, 'C:/Users/urvas/Projects/Dry Beans Classification Projects/Programs Used/Models/My_Model_4.h5');
```