Model Development Phase - 2

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Project Title	CardMaster: Intelligent Playing Card Recognition using Transfer Learning

Initial Model Training Code:

VGG 16:

```
#creating new model
vgg16 = Model(vgg.input,output)
```

```
#multi-class classification, optimization algorithm, tracking accuracy
vgg16.compile(loss='categorical_crossentropy',optimizer='adam',metrics=['accuracy'])
```

```
#training model on 15 epochs
vgg16.fit(train,epochs=15,validation_data=val,steps_per_epoch=len(train),validation_steps=len(val))
```

Inception V3:

```
#Create final model
inception = Model(inputs=base_model.input, outputs=predictions)

#compile the model
inception.compile(optimizer=Adam(learning_rate=0.001), loss='categorical_crossentropy', metrics=['accuracy'])

#training model
inception.fit(train,epochs=15,validation_data=val,steps_per_epoch=len(train),validation_steps=len(val))
```

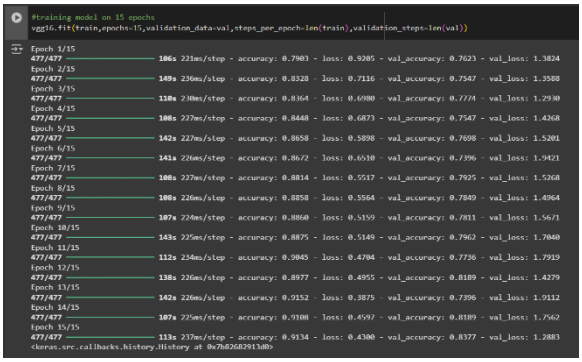
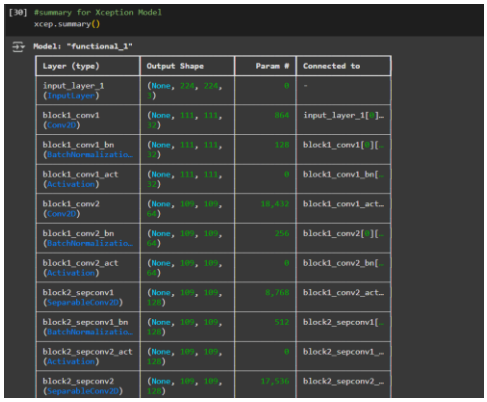
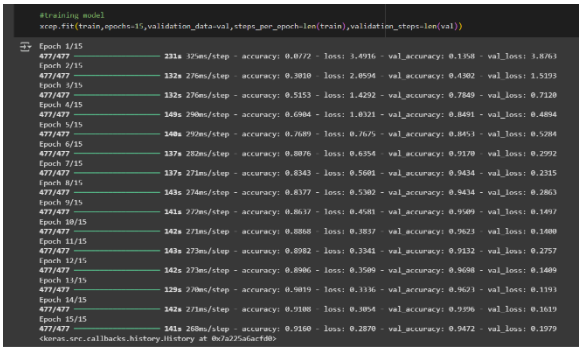
Xception:

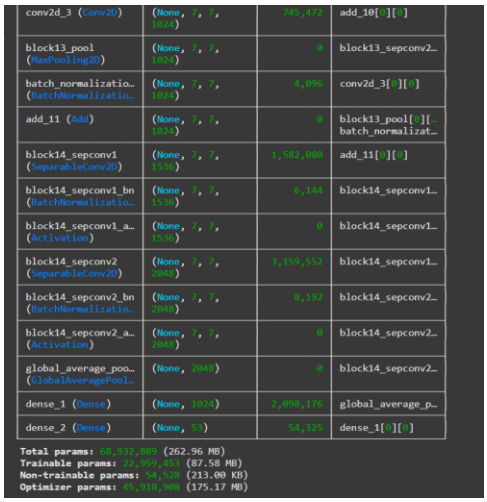
```
#Create final model
xcep = Model(inputs=xception.input, outputs=predictions)

#compile the model
xcep.compile(optimizer=Adam(learning_rate=0.001), loss='categorical_crossentropy', metrics=['accuracy'])

#training model
xcep.fit(train,epochs=15,validation_data=val,steps_per_epoch=len(train),validation_steps=len(val))
```

Model Validation and Evaluation Report:

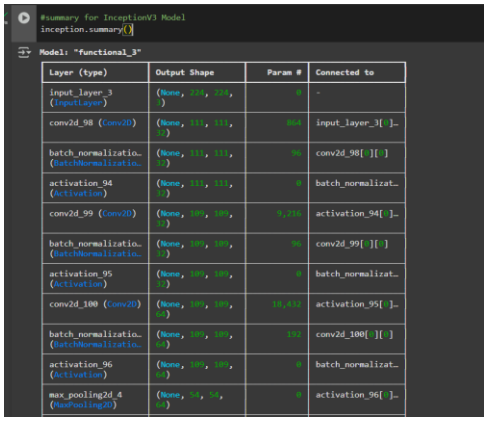
Model	Summary	Training and Validation Performance Metrics
VGG16		 Accuracy: **0.9134** Loss: **0.4300** Validation Accuracy: **0.8377** Validation Loss: **1.2883**
Xception		 Accuracy: **0.9160** Loss: **0.2870** Validation Accuracy: **0.9427** Validation Loss: **0.1979**



Layer (type)	Output Shape	Param #	Connected to
conv2d_3 (Conv2D)	(None, 7, 7, 1024)	745,472	add_10[0][0]
block13_pool (MaxPooling2D)	(None, 7, 7, 1024)	0	block13_sepconv2…
batch_normalizatio… (BatchNormalizatio…	(None, 7, 7, 1024)	4,096	conv2d_3[0][0]
add_11 (Add)	(None, 7, 7, 1024)	0	block13_pool[0][batch_normalizat…
block14_sepconv1 (SeparableConv2D)	(None, 7, 7, 1536)	1,582,080	add_11[0][0]
block14_sepconv1_bn (BatchNormalizatio…	(None, 7, 7, 1536)	6,144	block14_sepconv1…
block14_sepconv1_a… (Activation)	(None, 7, 7, 1536)	0	block14_sepconv1…
block14_sepconv2 (SeparableConv2D)	(None, 7, 7, 2048)	3,159,552	block14_sepconv1…
block14_sepconv2_bn (BatchNormalizatio…	(None, 7, 7, 2048)	8,192	block14_sepconv2…
block14_sepconv2_a… (Activation)	(None, 7, 7, 2048)	0	block14_sepconv2…
global_average_poo… (GlobalAveragePool…	(None, 2048)	0	block14_sepconv2…
dense_1 (Dense)	(None, 1024)	2,098,176	global_average_p…
dense_2 (Dense)	(None, 53)	54,325	dense_1[0][0]

Total params: 68,932,885 (262.96 MB)
Trainable params: 22,950,453 (87.58 MB)
Non-trainable params: 54,528 (213.00 KB)
Optimizer params: 45,918,908 (175.17 MB)

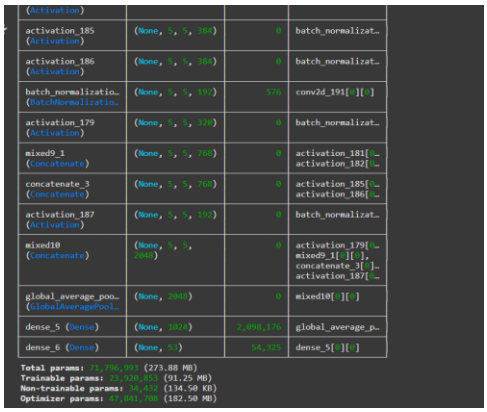
Inception V3



```
#summary for InceptionV3 Model
inception.summary()
```

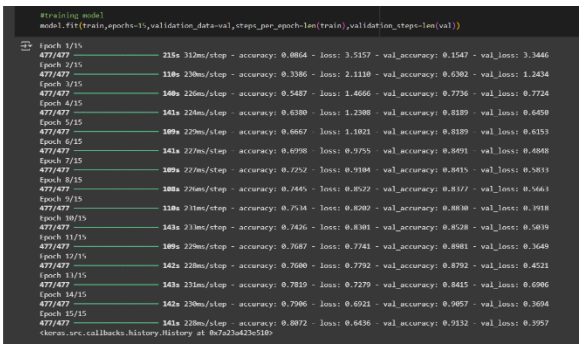
Model: "functional_3"

Layer (type)	Output Shape	Param #	Connected to
input_layer_3 (InputLayer)	(None, 229, 229, 3)	0	-
conv2d_98 (Conv2D)	(None, 113, 111, 32)	864	input_layer_3[0]…
batch_normalizatio… (BatchNormalizatio…	(None, 113, 111, 32)	96	conv2d_98[0][0]
activation_94 (Activation)	(None, 113, 111, 32)	0	batch_normalizat…
conv2d_99 (Conv2D)	(None, 109, 109, 32)	9,216	activation_94[0]…
batch_normalizatio… (BatchNormalizatio…	(None, 109, 109, 32)	96	conv2d_99[0][0]
activation_95 (Activation)	(None, 109, 109, 32)	0	batch_normalizat…
conv2d_100 (Conv2D)	(None, 109, 109, 64)	18,432	activation_95[0]…
batch_normalizatio… (BatchNormalizatio…	(None, 109, 109, 64)	192	conv2d_100[0][0]
activation_96 (Activation)	(None, 109, 109, 64)	0	batch_normalizat…
max_pooling2d_4 (MaxPooling2D)	(None, 54, 54, 64)	0	activation_96[0]…



(Activation)			
activation_185 (Activation)	(None, 3, 3, 384)	0	batch_normalizat…
activation_186 (Activation)	(None, 3, 3, 384)	0	batch_normalizat…
batch_normalizatio… (BatchNormalizatio…	(None, 3, 3, 192)	576	conv2d_191[0][0]
activation_179 (Activation)	(None, 3, 3, 320)	0	batch_normalizat…
mixed9_1 (Concatenate)	(None, 3, 3, 768)	0	activation_181[0… activation_182[0…
concatenate_3 (Concatenate)	(None, 3, 3, 768)	0	activation_185[0… activation_186[0…
activation_187 (Activation)	(None, 3, 3, 192)	0	batch_normalizat…
mixed10 (Concatenate)	(None, 3, 3, 2048)	0	activation_179[0… mixed9_1[0][0], concatenate_3[0]… activation_187[0…
global_average_poo… (GlobalAveragePool…	(None, 2048)	0	mixed10[0][0]
dense_5 (Dense)	(None, 1024)	2,098,176	global_average_p…
dense_6 (Dense)	(None, 53)	54,325	dense_5[0][0]

Total params: 23,926,693 (273.88 MB)
Trainable params: 23,920,933 (91.25 MB)
Non-trainable params: 34,432 (134.50 KB)
Optimizer params: 47,041,700 (182.50 MB)



```
#training model
model.fit(train,epochs=15,validation_data=val,steps_per_epoch=len(train),validation_steps=len(val))
```

```
Epoch 1/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 215s 312ms/step - accuracy: 0.0864 - loss: 3.5157 - val_accuracy: 0.1547 - val_loss: 3.3446
Epoch 2/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 110s 230ms/step - accuracy: 0.3386 - loss: 2.1110 - val_accuracy: 0.6302 - val_loss: 1.2434
Epoch 3/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 140s 226ms/step - accuracy: 0.5487 - loss: 1.4666 - val_accuracy: 0.7736 - val_loss: 0.7724
Epoch 4/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 141s 224ms/step - accuracy: 0.6300 - loss: 1.2308 - val_accuracy: 0.8189 - val_loss: 0.6450
Epoch 5/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 109s 229ms/step - accuracy: 0.6667 - loss: 1.1021 - val_accuracy: 0.8189 - val_loss: 0.6153
Epoch 6/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 141s 227ms/step - accuracy: 0.6998 - loss: 0.9755 - val_accuracy: 0.8491 - val_loss: 0.4848
Epoch 7/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 109s 227ms/step - accuracy: 0.7252 - loss: 0.9104 - val_accuracy: 0.8415 - val_loss: 0.5033
Epoch 8/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 108s 226ms/step - accuracy: 0.7445 - loss: 0.8522 - val_accuracy: 0.8377 - val_loss: 0.5663
Epoch 9/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 110s 231ms/step - accuracy: 0.7534 - loss: 0.8202 - val_accuracy: 0.8830 - val_loss: 0.3918
Epoch 10/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 143s 231ms/step - accuracy: 0.7426 - loss: 0.8301 - val_accuracy: 0.8528 - val_loss: 0.5039
Epoch 11/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 109s 229ms/step - accuracy: 0.7687 - loss: 0.7741 - val_accuracy: 0.8981 - val_loss: 0.3649
Epoch 12/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 142s 228ms/step - accuracy: 0.7600 - loss: 0.7792 - val_accuracy: 0.8792 - val_loss: 0.4521
Epoch 13/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 143s 231ms/step - accuracy: 0.7819 - loss: 0.7279 - val_accuracy: 0.8415 - val_loss: 0.6906
Epoch 14/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 142s 230ms/step - accuracy: 0.7906 - loss: 0.6921 - val_accuracy: 0.9057 - val_loss: 0.3694
Epoch 15/15
477/477 ━━━━━━━━━━━━━━━━━━━━ 141s 228ms/step - accuracy: 0.8072 - loss: 0.6436 - val_accuracy: 0.9132 - val_loss: 0.3957
<keras.src.callbacks.history.History at 0x7a23a423e510>
```

Accuracy: **0.8072**
Loss: **0.6436**
Validation Accuracy: **0.9132**
Validation Loss: **0.3975**

Conclusion:

After evaluating all three models — VGG16, Inception V3, and Xception — on the basis of training and validation performance, Xception clearly outperformed the others.It achieved the highest validation accuracy (94.27%) and the lowest validation loss (0.1979), indicating better generalization and learning efficiency. Also, it maintained low training loss with high accuracy, showing stable convergence without overfitting.

VGG16, despite high training accuracy (91.34%), showed a significant drop in validation accuracy (83.77%) and a higher validation loss, which suggests **overfitting** — it learned training data too well but failed to generalize.

Inception V3 had a validation accuracy (91.32%) higher than its training accuracy (80.72%), which is unusual and indicates possible **underfitting** or insufficient training — the model wasn't able to capture enough patterns from the training data.

Hence, Xception was selected as the final model for this project due to its superior performance and computational efficiency.