FINE TUNING THE PRETRAINED MODEL

```
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.models import load_model
from tensorflow.keras.applications import InceptionV3
from tensorflow.keras.layers import Dense, GlobalAveragePooling2D, BatchNormalization
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import EarlyStopping, ModelCheckpoint
from sklearn.utils.class_weight import compute_class_weight
```

```
# Step 1: Load the pre-trained model
model = load_model('/content/drive/MyDrive/diabetic_retinopathy_binary_model.h5')
```

```
WARNING:absl:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_metrics` will be empty until you t
```

```
# Unfreeze the top layers of the pre-trained model for fine-tuning
# Assuming the first 249 layers belong to InceptionV3 and should be kept frozen
for layer in model.layers[:249]:
    layer.trainable = False  # Freeze the first 249 layers
```

```
 #Unfreeze the remaining layers for fine-tuning
for layer in model.layers[249:]:
    layer.trainable = True  # Unfreeze the top layers for fine-tuning
```

```
model.summary()
```

Model: "functional"

Layer (type)	Output Shape	Param #	Connected to
input_layer (InputLayer)	(None, 299, 299, 3)	0	-
conv2d (Conv2D)	(None, 149, 149, 32)	864	input_layer[0][0]
batch_normalization (BatchNormalization)	(None, 149, 149, 32)	96	conv2d[0][0]
activation (Activation)	(None, 149, 149, 32)	0	batch_normalization[0…
conv2d_1 (Conv2D)	(None, 147, 147, 32)	9,216	activation[0][0]
batch_normalization_1 (BatchNormalization)	(None, 147, 147, 32)	96	conv2d_1[0][0]
activation_1 (Activation)	(None, 147, 147, 32)	0	batch_normalization_1…
conv2d_2 (Conv2D)	(None, 147, 147, 64)	18,432	activation_1[0][0]
batch_normalization_2 (BatchNormalization)	(None, 147, 147, 64)	192	conv2d_2[0][0]
activation_2 (Activation)	(None, 147, 147, 64)	0	batch_normalization_2…
max_pooling2d (MaxPooling2D)	(None, 73, 73, 64)	0	activation_2[0][0]
conv2d_3 (Conv2D)	(None, 73, 73, 80)	5,120	max_pooling2d[0][0]
batch_normalization_3 (BatchNormalization)	(None, 73, 73, 80)	240	conv2d_3[0][0]
activation_3 (Activation)	(None, 73, 73, 80)	0	batch_normalization_3…
conv2d_4 (Conv2D)	(None, 71, 71, 192)	138,240	activation_3[0][0]
batch_normalization_4 (BatchNormalization)	(None, 71, 71, 192)	576	conv2d_4[0][0]
activation_4 (Activation)	(None, 71, 71, 192)	0	batch_normalization_4…
max_pooling2d_1 (MaxPooling2D)	(None, 35, 35, 192)	0	activation_4[0][0]
conv2d_8 (Conv2D)	(None, 35, 35, 64)	12,288	max_pooling2d_1[0][0]

batch_normalization_8 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_8[0][0]
activation_8 (Activation)	(None, 35, 35, 64)	0	batch_normalization_8…
conv2d_6 (Conv2D)	(None, 35, 35, 48)	9,216	max_pooling2d_1[0][0]
conv2d_9 (Conv2D)	(None, 35, 35, 96)	55,296	activation_8[0][0]
batch_normalization_6 (BatchNormalization)	(None, 35, 35, 48)	144	conv2d_6[0][0]
batch_normalization_9 (BatchNormalization)	(None, 35, 35, 96)	288	conv2d_9[0][0]
activation_6 (Activation)	(None, 35, 35, 48)	0	batch_normalization_6…
activation_9 (Activation)	(None, 35, 35, 96)	0	batch_normalization_9…
average_pooling2d (AveragePooling2D)	(None, 35, 35, 192)	0	max_pooling2d_1[0][0]
conv2d_5 (Conv2D)	(None, 35, 35, 64)	12,288	max_pooling2d_1[0][0]
conv2d_7 (Conv2D)	(None, 35, 35, 64)	76,800	activation_6[0][0]
conv2d_10 (Conv2D)	(None, 35, 35, 96)	82,944	activation_9[0][0]
conv2d_11 (Conv2D)	(None, 35, 35, 32)	6,144	average_pooling2d[0][…
batch_normalization_5 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_5[0][0]
batch_normalization_7 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_7[0][0]
batch_normalization_10 (BatchNormalization)	(None, 35, 35, 96)	288	conv2d_10[0][0]
batch_normalization_11 (BatchNormalization)	(None, 35, 35, 32)	96	conv2d_11[0][0]
activation_5 (Activation)	(None, 35, 35, 64)	0	batch_normalization_5…
activation_7 (Activation)	(None, 35, 35, 64)	0	batch_normalization_7…
activation_10 (Activation)	(None, 35, 35, 96)	0	batch_normalization_1…
activation_11	(None, 35, 35, 32)	0	batch_normalization_1

(Activation)	(None, 35, 35, 32)	0	batch_normalization_1…
mixed0 (Concatenate)	(None, 35, 35, 256)	0	activation_5[0][0], activation_7[0][0], activation_10[0][0], activation_11[0][0]
conv2d_15 (Conv2D)	(None, 35, 35, 64)	16,384	mixed0[0][0]
batch_normalization_15 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_15[0][0]
activation_15 (Activation)	(None, 35, 35, 64)	0	batch_normalization_1…
conv2d_13 (Conv2D)	(None, 35, 35, 48)	12,288	mixed0[0][0]
conv2d_16 (Conv2D)	(None, 35, 35, 96)	55,296	activation_15[0][0]
batch_normalization_13 (BatchNormalization)	(None, 35, 35, 48)	144	conv2d_13[0][0]
batch_normalization_16 (BatchNormalization)	(None, 35, 35, 96)	288	conv2d_16[0][0]
activation_13 (Activation)	(None, 35, 35, 48)	0	batch_normalization_1…
activation_16 (Activation)	(None, 35, 35, 96)	0	batch_normalization_1…
average_pooling2d_1 (AveragePooling2D)	(None, 35, 35, 256)	0	mixed0[0][0]
conv2d_12 (Conv2D)	(None, 35, 35, 64)	16,384	mixed0[0][0]
conv2d_14 (Conv2D)	(None, 35, 35, 64)	76,800	activation_13[0][0]
conv2d_17 (Conv2D)	(None, 35, 35, 96)	82,944	activation_16[0][0]
conv2d_18 (Conv2D)	(None, 35, 35, 64)	16,384	average_pooling2d_1[0…
batch_normalization_12 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_12[0][0]
batch_normalization_14 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_14[0][0]
batch_normalization_17	(None, 35, 35, 96)	288	conv2d_17[0][0]

(BatchNormalization)			
batch_normalization_18 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_18[0][0]
activation_12 (Activation)	(None, 35, 35, 64)	0	batch_normalization_1…
activation_14 (Activation)	(None, 35, 35, 64)	0	batch_normalization_1…
activation_17 (Activation)	(None, 35, 35, 96)	0	batch_normalization_1…
activation_18 (Activation)	(None, 35, 35, 64)	0	batch_normalization_1…
mixed1 (Concatenate)	(None, 35, 35, 288)	0	activation_12[0][0], activation_14[0][0], activation_17[0][0], activation_18[0][0]
conv2d_22 (Conv2D)	(None, 35, 35, 64)	18,432	mixed1[0][0]
batch_normalization_22 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_22[0][0]
activation_22 (Activation)	(None, 35, 35, 64)	0	batch_normalization_2…
conv2d_20 (Conv2D)	(None, 35, 35, 48)	13,824	mixed1[0][0]
conv2d_23 (Conv2D)	(None, 35, 35, 96)	55,296	activation_22[0][0]
batch_normalization_20 (BatchNormalization)	(None, 35, 35, 48)	144	conv2d_20[0][0]
batch_normalization_23 (BatchNormalization)	(None, 35, 35, 96)	288	conv2d_23[0][0]
activation_20 (Activation)	(None, 35, 35, 48)	0	batch_normalization_2…
activation_23 (Activation)	(None, 35, 35, 96)	0	batch_normalization_2…
average_pooling2d_2 (AveragePooling2D)	(None, 35, 35, 288)	0	mixed1[0][0]
conv2d_19 (Conv2D)	(None, 35, 35, 64)	18,432	mixed1[0][0]

conv2d_21 (Conv2D)	(None, 35, 35, 64)	76,800	activation_20[0][0]
conv2d_24 (Conv2D)	(None, 35, 35, 96)	82,944	activation_23[0][0]
conv2d_25 (Conv2D)	(None, 35, 35, 64)	18,432	average_pooling2d_2[0…
batch_normalization_19 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_19[0][0]
batch_normalization_21 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_21[0][0]
batch_normalization_24 (BatchNormalization)	(None, 35, 35, 96)	288	conv2d_24[0][0]
batch_normalization_25 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_25[0][0]
activation_19 (Activation)	(None, 35, 35, 64)	0	batch_normalization_1…
activation_21 (Activation)	(None, 35, 35, 64)	0	batch_normalization_2…
activation_24 (Activation)	(None, 35, 35, 96)	0	batch_normalization_2…
activation_25 (Activation)	(None, 35, 35, 64)	0	batch_normalization_2…
mixed2 (Concatenate)	(None, 35, 35, 288)	0	activation_19[0][0], activation_21[0][0], activation_24[0][0], activation_25[0][0]
conv2d_27 (Conv2D)	(None, 35, 35, 64)	18,432	mixed2[0][0]
batch_normalization_27 (BatchNormalization)	(None, 35, 35, 64)	192	conv2d_27[0][0]
activation_27 (Activation)	(None, 35, 35, 64)	0	batch_normalization_2…
conv2d_28 (Conv2D)	(None, 35, 35, 96)	55,296	activation_27[0][0]
batch_normalization_28 (BatchNormalization)	(None, 35, 35, 96)	288	conv2d_28[0][0]

activation_28 (Activation)	(None, 35, 35, 96)	0	batch_normalization_2…
conv2d_26 (Conv2D)	(None, 17, 17, 384)	995,328	mixed2[0][0]
conv2d_29 (Conv2D)	(None, 17, 17, 96)	82,944	activation_28[0][0]
batch_normalization_26 (BatchNormalization)	(None, 17, 17, 384)	1,152	conv2d_26[0][0]
batch_normalization_29 (BatchNormalization)	(None, 17, 17, 96)	288	conv2d_29[0][0]
activation_26 (Activation)	(None, 17, 17, 384)	0	batch_normalization_2…
activation_29 (Activation)	(None, 17, 17, 96)	0	batch_normalization_2…
max_pooling2d_2 (MaxPooling2D)	(None, 17, 17, 288)	0	mixed2[0][0]
mixed3 (Concatenate)	(None, 17, 17, 768)	0	activation_26[0][0], activation_29[0][0], max_pooling2d_2[0][0]
conv2d_34 (Conv2D)	(None, 17, 17, 128)	98,304	mixed3[0][0]
batch_normalization_34 (BatchNormalization)	(None, 17, 17, 128)	384	conv2d_34[0][0]
activation_34 (Activation)	(None, 17, 17, 128)	0	batch_normalization_3…
conv2d_35 (Conv2D)	(None, 17, 17, 128)	114,688	activation_34[0][0]
batch_normalization_35 (BatchNormalization)	(None, 17, 17, 128)	384	conv2d_35[0][0]
activation_35 (Activation)	(None, 17, 17, 128)	0	batch_normalization_3…
conv2d_31 (Conv2D)	(None, 17, 17, 128)	98,304	mixed3[0][0]
conv2d_36 (Conv2D)	(None, 17, 17, 128)	114,688	activation_35[0][0]
batch_normalization_31 (BatchNormalization)	(None, 17, 17, 128)	384	conv2d_31[0][0]
batch_normalization_36	(None, 17, 17, 128)	384	conv2d_36[0][0]

(BatchNormalization)			
activation_31 (Activation)	(None, 17, 17, 128)	0	batch_normalization_3…
activation_36 (Activation)	(None, 17, 17, 128)	0	batch_normalization_3…
conv2d_32 (Conv2D)	(None, 17, 17, 128)	114,688	activation_31[0][0]
conv2d_37 (Conv2D)	(None, 17, 17, 128)	114,688	activation_36[0][0]
batch_normalization_32 (BatchNormalization)	(None, 17, 17, 128)	384	conv2d_32[0][0]
batch_normalization_37 (BatchNormalization)	(None, 17, 17, 128)	384	conv2d_37[0][0]
activation_32 (Activation)	(None, 17, 17, 128)	0	batch_normalization_3…
activation_37 (Activation)	(None, 17, 17, 128)	0	batch_normalization_3…
average_pooling2d_3 (AveragePooling2D)	(None, 17, 17, 768)	0	mixed3[0][0]
conv2d_30 (Conv2D)	(None, 17, 17, 192)	147,456	mixed3[0][0]
conv2d_33 (Conv2D)	(None, 17, 17, 192)	172,032	activation_32[0][0]
conv2d_38 (Conv2D)	(None, 17, 17, 192)	172,032	activation_37[0][0]
conv2d_39 (Conv2D)	(None, 17, 17, 192)	147,456	average_pooling2d_3[0…
batch_normalization_30 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_30[0][0]
batch_normalization_33 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_33[0][0]
batch_normalization_38 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_38[0][0]
batch_normalization_39 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_39[0][0]
activation_30 (Activation)	(None, 17, 17, 192)	0	batch_normalization_3…

activation_33 (Activation)	(None, 17, 17, 192)	0	batch_normalization_3…
activation_38 (Activation)	(None, 17, 17, 192)	0	batch_normalization_3…
activation_39 (Activation)	(None, 17, 17, 192)	0	batch_normalization_3…
mixed4 (Concatenate)	(None, 17, 17, 768)	0	activation_30[0][0], activation_33[0][0], activation_38[0][0], activation_39[0][0]
conv2d_44 (Conv2D)	(None, 17, 17, 160)	122,880	mixed4[0][0]
batch_normalization_44 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_44[0][0]
activation_44 (Activation)	(None, 17, 17, 160)	0	batch_normalization_4…
conv2d_45 (Conv2D)	(None, 17, 17, 160)	179,200	activation_44[0][0]
batch_normalization_45 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_45[0][0]
activation_45 (Activation)	(None, 17, 17, 160)	0	batch_normalization_4…
conv2d_41 (Conv2D)	(None, 17, 17, 160)	122,880	mixed4[0][0]
conv2d_46 (Conv2D)	(None, 17, 17, 160)	179,200	activation_45[0][0]
batch_normalization_41 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_41[0][0]
batch_normalization_46 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_46[0][0]
activation_41 (Activation)	(None, 17, 17, 160)	0	batch_normalization_4…
activation_46 (Activation)	(None, 17, 17, 160)	0	batch_normalization_4…
conv2d_42 (Conv2D)	(None, 17, 17, 160)	179,200	activation_41[0][0]
conv2d_47 (Conv2D)	(None, 17, 17, 160)	179,200	activation_46[0][0]

batch_normalization_42 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_42[0][0]
batch_normalization_47 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_47[0][0]
activation_42 (Activation)	(None, 17, 17, 160)	0	batch_normalization_4…
activation_47 (Activation)	(None, 17, 17, 160)	0	batch_normalization_4…
average_pooling2d_4 (AveragePooling2D)	(None, 17, 17, 768)	0	mixed4[0][0]
conv2d_40 (Conv2D)	(None, 17, 17, 192)	147,456	mixed4[0][0]
conv2d_43 (Conv2D)	(None, 17, 17, 192)	215,040	activation_42[0][0]
conv2d_48 (Conv2D)	(None, 17, 17, 192)	215,040	activation_47[0][0]
conv2d_49 (Conv2D)	(None, 17, 17, 192)	147,456	average_pooling2d_4[0…
batch_normalization_40 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_40[0][0]
batch_normalization_43 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_43[0][0]
batch_normalization_48 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_48[0][0]
batch_normalization_49 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_49[0][0]
activation_40 (Activation)	(None, 17, 17, 192)	0	batch_normalization_4…
activation_43 (Activation)	(None, 17, 17, 192)	0	batch_normalization_4…
activation_48 (Activation)	(None, 17, 17, 192)	0	batch_normalization_4…
activation_49 (Activation)	(None, 17, 17, 192)	0	batch_normalization_4…
mixed5 (Concatenate)	(None, 17, 17, 768)	0	activation_40[0][0],

			activation_43[0][0], activation_48[0][0], activation_49[0][0]
conv2d_54 (Conv2D)	(None, 17, 17, 160)	122,880	mixed5[0][0]
batch_normalization_54 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_54[0][0]
activation_54 (Activation)	(None, 17, 17, 160)	0	batch_normalization_5…
conv2d_55 (Conv2D)	(None, 17, 17, 160)	179,200	activation_54[0][0]
batch_normalization_55 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_55[0][0]
activation_55 (Activation)	(None, 17, 17, 160)	0	batch_normalization_5…
conv2d_51 (Conv2D)	(None, 17, 17, 160)	122,880	mixed5[0][0]
conv2d_56 (Conv2D)	(None, 17, 17, 160)	179,200	activation_55[0][0]
batch_normalization_51 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_51[0][0]
batch_normalization_56 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_56[0][0]
activation_51 (Activation)	(None, 17, 17, 160)	0	batch_normalization_5…
activation_56 (Activation)	(None, 17, 17, 160)	0	batch_normalization_5…
conv2d_52 (Conv2D)	(None, 17, 17, 160)	179,200	activation_51[0][0]
conv2d_57 (Conv2D)	(None, 17, 17, 160)	179,200	activation_56[0][0]
batch_normalization_52 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_52[0][0]
batch_normalization_57 (BatchNormalization)	(None, 17, 17, 160)	480	conv2d_57[0][0]
activation_52 (Activation)	(None, 17, 17, 160)	0	batch_normalization_5…
activation_57	(None, 17, 17, 160)	0	batch_normalization_5…

(Activation)			
average_pooling2d_5 (AveragePooling2D)	(None, 17, 17, 768)	0	mixed5[0][0]
conv2d_50 (Conv2D)	(None, 17, 17, 192)	147,456	mixed5[0][0]
conv2d_53 (Conv2D)	(None, 17, 17, 192)	215,040	activation_52[0][0]
conv2d_58 (Conv2D)	(None, 17, 17, 192)	215,040	activation_57[0][0]
conv2d_59 (Conv2D)	(None, 17, 17, 192)	147,456	average_pooling2d_5[0…
batch_normalization_50 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_50[0][0]
batch_normalization_53 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_53[0][0]
batch_normalization_58 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_58[0][0]
batch_normalization_59 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_59[0][0]
activation_50 (Activation)	(None, 17, 17, 192)	0	batch_normalization_5…
activation_53 (Activation)	(None, 17, 17, 192)	0	batch_normalization_5…
activation_58 (Activation)	(None, 17, 17, 192)	0	batch_normalization_5…
activation_59 (Activation)	(None, 17, 17, 192)	0	batch_normalization_5…
mixed6 (Concatenate)	(None, 17, 17, 768)	0	activation_50[0][0], activation_53[0][0], activation_58[0][0], activation_59[0][0]
conv2d_64 (Conv2D)	(None, 17, 17, 192)	147,456	mixed6[0][0]
batch_normalization_64 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_64[0][0]
activation_64 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…

conv2d_65 (Conv2D)	(None, 17, 17, 192)	258,048	activation_64[0][0]
batch_normalization_65 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_65[0][0]
activation_65 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…
conv2d_61 (Conv2D)	(None, 17, 17, 192)	147,456	mixed6[0][0]
conv2d_66 (Conv2D)	(None, 17, 17, 192)	258,048	activation_65[0][0]
batch_normalization_61 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_61[0][0]
batch_normalization_66 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_66[0][0]
activation_61 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…
activation_66 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…
conv2d_62 (Conv2D)	(None, 17, 17, 192)	258,048	activation_61[0][0]
conv2d_67 (Conv2D)	(None, 17, 17, 192)	258,048	activation_66[0][0]
batch_normalization_62 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_62[0][0]
batch_normalization_67 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_67[0][0]
activation_62 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…
activation_67 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…
average_pooling2d_6 (AveragePooling2D)	(None, 17, 17, 768)	0	mixed6[0][0]
conv2d_60 (Conv2D)	(None, 17, 17, 192)	147,456	mixed6[0][0]
conv2d_63 (Conv2D)	(None, 17, 17, 192)	258,048	activation_62[0][0]
conv2d_68 (Conv2D)	(None, 17, 17, 192)	258,048	activation_67[0][0]

conv2d_69 (Conv2D)	(None, 17, 17, 192)	147,456	average_pooling2d_6[0…
batch_normalization_60 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_60[0][0]
batch_normalization_63 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_63[0][0]
batch_normalization_68 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_68[0][0]
batch_normalization_69 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_69[0][0]
activation_60 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…
activation_63 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…
activation_68 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…
activation_69 (Activation)	(None, 17, 17, 192)	0	batch_normalization_6…
mixed7 (Concatenate)	(None, 17, 17, 768)	0	activation_60[0][0], activation_63[0][0], activation_68[0][0], activation_69[0][0]
conv2d_72 (Conv2D)	(None, 17, 17, 192)	147,456	mixed7[0][0]
batch_normalization_72 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_72[0][0]
activation_72 (Activation)	(None, 17, 17, 192)	0	batch_normalization_7…
conv2d_73 (Conv2D)	(None, 17, 17, 192)	258,048	activation_72[0][0]
batch_normalization_73 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_73[0][0]
activation_73 (Activation)	(None, 17, 17, 192)	0	batch_normalization_7…
conv2d_70 (Conv2D)	(None, 17, 17, 192)	147,456	mixed7[0][0]
conv2d_74 (Conv2D)	(None, 17, 17, 192)	258,048	activation_73[0][0]

conv2d_74 (Conv2D)	(None, 17, 17, 192)	258,048	activation_73[0][0]
batch_normalization_70 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_70[0][0]
batch_normalization_74 (BatchNormalization)	(None, 17, 17, 192)	576	conv2d_74[0][0]
activation_70 (Activation)	(None, 17, 17, 192)	0	batch_normalization_7…
activation_74 (Activation)	(None, 17, 17, 192)	0	batch_normalization_7…
conv2d_71 (Conv2D)	(None, 8, 8, 320)	552,960	activation_70[0][0]
conv2d_75 (Conv2D)	(None, 8, 8, 192)	331,776	activation_74[0][0]
batch_normalization_71 (BatchNormalization)	(None, 8, 8, 320)	960	conv2d_71[0][0]
batch_normalization_75 (BatchNormalization)	(None, 8, 8, 192)	576	conv2d_75[0][0]
activation_71 (Activation)	(None, 8, 8, 320)	0	batch_normalization_7…
activation_75 (Activation)	(None, 8, 8, 192)	0	batch_normalization_7…
max_pooling2d_3 (MaxPooling2D)	(None, 8, 8, 768)	0	mixed7[0][0]
mixed8 (Concatenate)	(None, 8, 8, 1280)	0	activation_71[0][0], activation_75[0][0], max_pooling2d_3[0][0]
conv2d_80 (Conv2D)	(None, 8, 8, 448)	573,440	mixed8[0][0]
batch_normalization_80 (BatchNormalization)	(None, 8, 8, 448)	1,344	conv2d_80[0][0]
activation_80 (Activation)	(None, 8, 8, 448)	0	batch_normalization_8…
conv2d_77 (Conv2D)	(None, 8, 8, 384)	491,520	mixed8[0][0]
conv2d_81 (Conv2D)	(None, 8, 8, 384)	1,548,288	activation_80[0][0]
batch_normalization_77	(None, 8, 8, 384)	1,152	conv2d_77[0][0]

(BatchNormalization)			
batch_normalization_81 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_81[0][0]
activation_77 (Activation)	(None, 8, 8, 384)	0	batch_normalization_7…
activation_81 (Activation)	(None, 8, 8, 384)	0	batch_normalization_8…
conv2d_78 (Conv2D)	(None, 8, 8, 384)	442,368	activation_77[0][0]
conv2d_79 (Conv2D)	(None, 8, 8, 384)	442,368	activation_77[0][0]
conv2d_82 (Conv2D)	(None, 8, 8, 384)	442,368	activation_81[0][0]
conv2d_83 (Conv2D)	(None, 8, 8, 384)	442,368	activation_81[0][0]
average_pooling2d_7 (AveragePooling2D)	(None, 8, 8, 1280)	0	mixed8[0][0]
conv2d_76 (Conv2D)	(None, 8, 8, 320)	409,600	mixed8[0][0]
batch_normalization_78 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_78[0][0]
batch_normalization_79 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_79[0][0]
batch_normalization_82 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_82[0][0]
batch_normalization_83 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_83[0][0]
conv2d_84 (Conv2D)	(None, 8, 8, 192)	245,760	average_pooling2d_7[0…
batch_normalization_76 (BatchNormalization)	(None, 8, 8, 320)	960	conv2d_76[0][0]
activation_78 (Activation)	(None, 8, 8, 384)	0	batch_normalization_7…
activation_79 (Activation)	(None, 8, 8, 384)	0	batch_normalization_7…
activation_82 (Activation)	(None, 8, 8, 384)	0	batch_normalization_8…

activation_83 (Activation)	(None, 8, 8, 384)	0	batch_normalization_8…
batch_normalization_84 (BatchNormalization)	(None, 8, 8, 192)	576	conv2d_84[0][0]
activation_76 (Activation)	(None, 8, 8, 320)	0	batch_normalization_7…
mixed9_0 (Concatenate)	(None, 8, 8, 768)	0	activation_78[0][0], activation_79[0][0]
concatenate (Concatenate)	(None, 8, 8, 768)	0	activation_82[0][0], activation_83[0][0]
activation_84 (Activation)	(None, 8, 8, 192)	0	batch_normalization_8…
mixed9 (Concatenate)	(None, 8, 8, 2048)	0	activation_76[0][0], mixed9_0[0][0], concatenate[0][0], activation_84[0][0]
conv2d_89 (Conv2D)	(None, 8, 8, 448)	917,504	mixed9[0][0]
batch_normalization_89 (BatchNormalization)	(None, 8, 8, 448)	1,344	conv2d_89[0][0]
activation_89 (Activation)	(None, 8, 8, 448)	0	batch_normalization_8…
conv2d_86 (Conv2D)	(None, 8, 8, 384)	786,432	mixed9[0][0]
conv2d_90 (Conv2D)	(None, 8, 8, 384)	1,548,288	activation_89[0][0]
batch_normalization_86 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_86[0][0]
batch_normalization_90 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_90[0][0]
activation_86 (Activation)	(None, 8, 8, 384)	0	batch_normalization_8…
activation_90 (Activation)	(None, 8, 8, 384)	0	batch_normalization_9…
conv2d_87 (Conv2D)	(None, 8, 8, 384)	442,368	activation_86[0][0]

conv2d_88 (Conv2D)	(None, 8, 8, 384)	442,368	activation_86[0][0]
conv2d_91 (Conv2D)	(None, 8, 8, 384)	442,368	activation_90[0][0]
conv2d_92 (Conv2D)	(None, 8, 8, 384)	442,368	activation_90[0][0]
average_pooling2d_8 (AveragePooling2D)	(None, 8, 8, 2048)	0	mixed9[0][0]
conv2d_85 (Conv2D)	(None, 8, 8, 320)	655,360	mixed9[0][0]
batch_normalization_87 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_87[0][0]
batch_normalization_88 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_88[0][0]
batch_normalization_91 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_91[0][0]
batch_normalization_92 (BatchNormalization)	(None, 8, 8, 384)	1,152	conv2d_92[0][0]

```
# Step 2: Recompile the model with a lower learning rate
model.compile(optimizer=Adam(learning_rate=1e-5), loss='binary_crossentropy', metrics=['accuracy'])


# Load CSV file containing image labels (DR or Not DR)
df_labels = pd.read_csv('/content/drive/MyDrive/labels_mbrset.csv')  # Replace with your CSV file path


# Convert DR labels to integers for class weight computation
df_labels['dr_diagnosis_int'] = df_labels['final_icdr'].apply(lambda x: 0 if x == 0 else 1)



# Define paths and parameters
IMG_SIZE = (299, 299)
BATCH_SIZE = 32
TRAIN_PATH = '/content/drive/MyDrive/images'



# ImageDataGenerator for training and validation
train_datagen = ImageDataGenerator(
    rescale=1./255,
    validation_split=0.2,  # Use 20% of data for validation
    rotation_range=20,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True
)


# Load training and validation data
train_generator = train_datagen.flow_from_dataframe(
    dataframe=df_labels,
    directory=TRAIN_PATH,
    x_col='file',  # Image filename column
    y_col='dr_diagnosis_int',  # Single binary output (DR or Not DR)
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode='raw',
    subset='training',
    shuffle=True
)
```

```
valid_generator = train_datagen.flow_from_dataframe(
    dataframe=df_labels,
    directory=TRAIN_PATH,
    x_col='file',
    y_col='dr_diagnosis_int',
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode='raw',
    subset='validation',
    shuffle=True
)
```

```
Found 4132 validated image filenames.
Found 1032 validated image filenames.
```

```
# Step 3: Handle class imbalance by computing class weights
class_weights = compute_class_weight('balanced', classes=np.unique(df_labels['dr_diagnosis_int']), y=df_labels['dr_diagnosis_int'])
class_weight_dict = dict(enumerate(class_weights))


# Step 4: Train the model with fine-tuning
checkpoint = ModelCheckpoint('best_finetuned_model.keras', monitor='val_loss', save_best_only=True, mode='min')
early_stopping = EarlyStopping(monitor='val_loss', patience=5, restore_best_weights=True)


history = model.fit(
    train_generator,
    epochs=10,  # Reduce the number of epochs to avoid overfitting during fine-tuning
    validation_data=valid_generator,
    class_weight=class_weight_dict,
    callbacks=[checkpoint, early_stopping],
    steps_per_epoch=train_generator.samples // BATCH_SIZE,
    validation_steps=valid_generator.samples // BATCH_SIZE
)
```

```
Epoch 1/10
/usr/local/lib/python3.10/dist-packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121: UserWarning: Your `PyDataset` class
  self._warn_if_super_not_called()
129/129 ━━━━━━━━━━━━━━━━━━━━ 2157s 16s/step - accuracy: 0.6940 - loss: 0.6021 - val_accuracy: 0.7480 - val_loss: 0.5398
Epoch 2/10
  1/129 ━━━━━━━━━━━━━━━━━━━━ 22:40 11s/step - accuracy: 0.5625 - loss: 0.8582/usr/lib/python3.10/contextlib.py:153: UserWarning: Your in
  self.gen.throw(typ, value, traceback)
129/129 ━━━━━━━━━━━━━━━━━━━━ 13s 15ms/step - accuracy: 0.5625 - loss: 0.8582 - val_accuracy: 0.6250 - val_loss: 0.6068
Epoch 3/10
```

```
129/129 ━━━━━━━━━━━━━━━━━━━━ 2012s 15s/step - accuracy: 0.7163 - loss: 0.5552 - val_accuracy: 0.7188 - val_loss: 0.5790
Epoch 4/10
129/129 ━━━━━━━━━━━━━━━━━━━━ 16s 31ms/step - accuracy: 0.6875 - loss: 0.4989 - val_accuracy: 0.7500 - val_loss: 0.4132
Epoch 5/10
129/129 ━━━━━━━━━━━━━━━━━━━━ 1966s 15s/step - accuracy: 0.7500 - loss: 0.5243 - val_accuracy: 0.7158 - val_loss: 0.5658
Epoch 6/10
129/129 ━━━━━━━━━━━━━━━━━━━━ 63s 419ms/step - accuracy: 0.7812 - loss: 0.6065 - val_accuracy: 0.6250 - val_loss: 0.7653
Epoch 7/10
129/129 ━━━━━━━━━━━━━━━━━━━━ 1997s 15s/step - accuracy: 0.7452 - loss: 0.5217 - val_accuracy: 0.7168 - val_loss: 0.5648
Epoch 8/10
129/129 ━━━━━━━━━━━━━━━━━━━━ 14s 15ms/step - accuracy: 0.8125 - loss: 0.4402 - val_accuracy: 0.7500 - val_loss: 0.6014
Epoch 9/10
129/129 ━━━━━━━━━━━━━━━━━━━━ 1953s 15s/step - accuracy: 0.7615 - loss: 0.4905 - val_accuracy: 0.7178 - val_loss: 0.5621
```

```
# Save the fine-tuned model
model.save('/content/drive/MyDrive/diabetic_retinopathy_finetuned_model.h5')
```

```
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This file format is consi
```

```
# Optional: Evaluate the model
val_predictions = model.predict(valid_generator)
val_predictions_binary = (val_predictions > 0.5).astype(int)
```

```
33/33 ━━━━━━━━━━━━━━━━━━━━ 355s 11s/step
```

```
# Performance evaluation
from sklearn.metrics import classification_report, confusion_matrix, roc_auc_score

true_labels = valid_generator.labels  # True labels from validation set

print(classification_report(true_labels, val_predictions_binary, target_names=['Not DR', 'DR']))

cm = confusion_matrix(true_labels, val_predictions_binary)
import seaborn as sns
import matplotlib.pyplot as plt
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=['Not DR', 'DR'], yticklabels=['Not DR', 'DR'])
plt.title('Confusion Matrix')
plt.show()

roc_auc = roc_auc_score(true_labels, val_predictions)
print(f'ROC AUC Score: {roc_auc:.4f}')
```

```
print(f'ROC AUC Score: {roc_auc:.4f}')
```

```
              precision    recall  f1-score   support

      Not DR       0.73      0.65      0.69       748
          DR       0.29      0.38      0.33       284

    accuracy                           0.58      1032
   macro avg       0.51      0.52      0.51      1032
weighted avg       0.61      0.58      0.59      1032
```