Práctica 2

January 29, 2026

1 1. Evaluar la red neuronal VGG16 entrenada con Imagenet para diagnosticar glaucoma

1.1 1.1. Determinar el rendimiento de la red VGG16 -con los pesos resultantes de su entrenamiento conImagenet- para diagnosticar el glaucoma (si/no) en las retinografías de la base de datos ACRIMA(p.e. https://www.kaggle.com/datasets/ayush02102001/glaucoma-classification-datasets)

Primero cargamos las librerías

[ ]:
```
# Paquetes más generales
import numpy as np
import os
import requests
import zipfile
import urllib.request
import shutil
import matplotlib.pyplot as plt
import seaborn as sns
import cv2

# Paquetes para la red
import tensorflow as tf
from tensorflow.keras import Sequential
from tensorflow.keras.layers import Dense, Conv2D, MaxPool2D, Flatten, Dropout
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.optimizers import Adam
from keras.callbacks import ModelCheckpoint, EarlyStopping
from tensorflow.keras.applications.vgg16 import preprocess_input
from tensorflow.keras.preprocessing.image import load_img, img_to_array

# Paquetes para precisión
from sklearn.metrics import classification_report, precision_score, f1_score,␣
↪recall_score, log_loss, brier_score_loss
from sklearn.metrics import roc_auc_score, roc_curve
from sklearn.metrics import classification_report, confusion_matrix
```

```
# Paquetes para cargar el modelo
from tensorflow.keras.applications import VGG16
from tensorflow.keras.models import Model
```

Cargamos la base de datos y al ser un archivo comprimido punto zip lo descomprimimos

[ ]:
```
zip_path = "/notebooks/ACRIMA.zip"
extract_path = "acrima_dataset"

# Descomprimirr
with zipfile.ZipFile(zip_path, 'r') as zip_ref:
    zip_ref.extractall(extract_path)

# Mostrar los primeros elementos de la carpeta extraída
os.listdir(extract_path)
```

[ ]:
```
['ACRIMA']
```

Utilizamos la división que ya esta creada en la base de datos para conjunto de entrenamiento y de test

[ ]:
```
# Rutas a los conjuntos de entrenamiento y test
train_dir = "/notebooks/acrima_dataset/ACRIMA/PARTITIONED/Training"
test_dir = "/notebooks/acrima_dataset/ACRIMA/PARTITIONED/Testing"

# Generadores con preprocesamiento de VGG16
datagen = ImageDataGenerator(preprocessing_function=preprocess_input)

# Crear generadores
train_generator = datagen.flow_from_directory(
    train_dir,
    target_size=(224, 224),
    batch_size=32,
    class_mode='binary'
)

test_generator = datagen.flow_from_directory(
    test_dir,
    target_size=(224, 224),
    batch_size=32,
    class_mode='binary',
    shuffle=False
)
```

```
Found 564 images belonging to 2 classes.
Found 141 images belonging to 2 classes.
```

Cargamos el modelo VGG16 con los pesos preentrenados en ImageNet. Sin embargo, esto presenta una limitación importante: la arquitectura original de VGG16 está diseñada para clasificación

multiclase sobre distintas categorías de objetos generales, no para una tarea de clasificación binaria como la que planteamos (glaucoma vs. normal). Para que podamos usarla para clasificar imágenes de dos categorías tenemos como mínimo que añadir una capa densa con una función sigmoide.

[ ]:
```
vgg16 = VGG16(weights='imagenet', include_top=False, input_shape=(224, 224, 3))

# Cogelamos las capas convolucionales
for layer in vgg16.layers:
    layer.trainable = False

# Añadir solo la última capa binaria
x = Flatten()(vgg16.output)
output = Dense(1, activation='sigmoid')(x)

# Definimos la red
model1 = Model(inputs=vgg16.input, outputs=output)
model1.compile(optimizer=Adam(1e-4), loss='binary_crossentropy',␣
 ↪metrics=['accuracy'])
```

```
2025-05-25 13:37:38.790530: I
external/local_xla/xla/stream_executor/cuda/cuda_executor.cc:901] successful
NUMA node read from SysFS had negative value (-1), but there must be at least
one NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355

Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5

2025-05-25 13:37:38.891079: I
external/local_xla/xla/stream_executor/cuda/cuda_executor.cc:901] successful
NUMA node read from SysFS had negative value (-1), but there must be at least
one NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
2025-05-25 13:37:38.891367: I
external/local_xla/xla/stream_executor/cuda/cuda_executor.cc:901] successful
NUMA node read from SysFS had negative value (-1), but there must be at least
one NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
2025-05-25 13:37:38.892550: I
external/local_xla/xla/stream_executor/cuda/cuda_executor.cc:901] successful
NUMA node read from SysFS had negative value (-1), but there must be at least
one NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
2025-05-25 13:37:38.892770: I
external/local_xla/xla/stream_executor/cuda/cuda_executor.cc:901] successful
```

```
NUMA node read from SysFS had negative value (-1), but there must be at least
one NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
2025-05-25 13:37:38.892956: I
external/local_xla/xla/stream_executor/cuda/cuda_executor.cc:901] successful
NUMA node read from SysFS had negative value (-1), but there must be at least
one NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
2025-05-25 13:37:39.167133: I
external/local_xla/xla/stream_executor/cuda/cuda_executor.cc:901] successful
NUMA node read from SysFS had negative value (-1), but there must be at least
one NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
2025-05-25 13:37:39.167376: I
external/local_xla/xla/stream_executor/cuda/cuda_executor.cc:901] successful
NUMA node read from SysFS had negative value (-1), but there must be at least
one NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
2025-05-25 13:37:39.167572: I
external/local_xla/xla/stream_executor/cuda/cuda_executor.cc:901] successful
NUMA node read from SysFS had negative value (-1), but there must be at least
one NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
2025-05-25 13:37:39.167706: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1929] Created device
/job:localhost/replica:0/task:0/device:GPU:0 with 15657 MB memory:  -> device:
0, name: Quadro P5000, pci bus id: 0000:00:05.0, compute capability: 6.1

58889256/58889256 [==============================] - 0s 0us/step
```

Cargamos estos callbacks para evaluar como se entrena la red y pararla si no mejora

[ ]:
```
checkpoint = ModelCheckpoint(
    "vgg16_custom.h5",
    monitor='val_loss',
    verbose=1,
    save_best_only=True,
    save_weights_only=False,
    mode='min')
early = EarlyStopping(
    monitor='val_loss',
    patience=50,
    verbose=1,
```

```
    restore_best_weights=True)
```

Entrenamos el modelo

[ ]:
```
history = model1.fit(
    train_generator,
    epochs=300,
    validation_data=test_generator,
    callbacks=[checkpoint, early])
```

```
Epoch 1/300

2025-05-25 13:37:50.793304: I
external/local_xla/xla/stream_executor/cuda/cuda_dnn.cc:454] Loaded cuDNN
version 8907
2025-05-25 13:37:57.236415: I external/local_xla/xla/service/service.cc:168] XLA
service 0x7f4998df7e70 initialized for platform CUDA (this does not guarantee
that XLA will be used). Devices:
2025-05-25 13:37:57.236652: I external/local_xla/xla/service/service.cc:176]
StreamExecutor device (0): Quadro P5000, Compute Capability 6.1
2025-05-25 13:37:57.278814: I
tensorflow/compiler/mlir/tensorflow/utils/dump_mlir_util.cc:269] disabling MLIR
crash reproducer, set env var `MLIR_CRASH_REPRODUCER_DIRECTORY` to enable.

 1/18 [>…] - ETA: 2:13 - loss: 1.4955 - accuracy:
0.7500

WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
I0000 00:00:1748180277.503653     394 device_compiler.h:186] Compiled cluster
using XLA!  This line is logged at most once for the lifetime of the process.

18/18 [==============================] - ETA: 0s - loss: 1.1932 - accuracy:
0.6454
Epoch 1: val_loss improved from inf to 0.88181, saving model to vgg16_custom.h5

/usr/local/lib/python3.11/dist-packages/keras/src/engine/training.py:3103:
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')`.
  saving_api.save_model(

18/18 [==============================] - 20s 730ms/step - loss: 1.1932 -
accuracy: 0.6454 - val_loss: 0.8818 - val_accuracy: 0.7021
Epoch 2/300
18/18 [==============================] - ETA: 0s - loss: 0.4977 - accuracy:
0.8316
Epoch 2: val_loss improved from 0.88181 to 0.62252, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 246ms/step - loss: 0.4977 -
accuracy: 0.8316 - val_loss: 0.6225 - val_accuracy: 0.8227
```

```
Epoch 3/300
18/18 [==============================] - ETA: 0s - loss: 0.2776 - accuracy:
0.9060
Epoch 3: val_loss improved from 0.62252 to 0.51089, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 154ms/step - loss: 0.2776 -
accuracy: 0.9060 - val_loss: 0.5109 - val_accuracy: 0.8511
Epoch 4/300
18/18 [==============================] - ETA: 0s - loss: 0.1612 - accuracy:
0.9433
Epoch 4: val_loss did not improve from 0.51089
18/18 [==============================] - 3s 148ms/step - loss: 0.1612 -
accuracy: 0.9433 - val_loss: 0.5634 - val_accuracy: 0.8582
Epoch 5/300
18/18 [==============================] - ETA: 0s - loss: 0.0997 - accuracy:
0.9699
Epoch 5: val_loss improved from 0.51089 to 0.47982, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 158ms/step - loss: 0.0997 -
accuracy: 0.9699 - val_loss: 0.4798 - val_accuracy: 0.8582
Epoch 6/300
18/18 [==============================] - ETA: 0s - loss: 0.0642 - accuracy:
0.9876
Epoch 6: val_loss did not improve from 0.47982
18/18 [==============================] - 3s 145ms/step - loss: 0.0642 -
accuracy: 0.9876 - val_loss: 0.4826 - val_accuracy: 0.8723
Epoch 7/300
18/18 [==============================] - ETA: 0s - loss: 0.0446 - accuracy:
0.9929
Epoch 7: val_loss did not improve from 0.47982
18/18 [==============================] - 3s 146ms/step - loss: 0.0446 -
accuracy: 0.9929 - val_loss: 0.4874 - val_accuracy: 0.8794
Epoch 8/300
18/18 [==============================] - ETA: 0s - loss: 0.0325 - accuracy:
0.9947
Epoch 8: val_loss did not improve from 0.47982
18/18 [==============================] - 3s 143ms/step - loss: 0.0325 -
accuracy: 0.9947 - val_loss: 0.4849 - val_accuracy: 0.8794
Epoch 9/300
18/18 [==============================] - ETA: 0s - loss: 0.0257 - accuracy:
0.9982
Epoch 9: val_loss did not improve from 0.47982
18/18 [==============================] - 3s 142ms/step - loss: 0.0257 -
accuracy: 0.9982 - val_loss: 0.4873 - val_accuracy: 0.8865
Epoch 10/300
18/18 [==============================] - ETA: 0s - loss: 0.0189 - accuracy:
0.9982
Epoch 10: val_loss improved from 0.47982 to 0.47835, saving model to
```

```
vgg16_custom.h5
18/18 [==============================] - 3s 160ms/step - loss: 0.0189 -
accuracy: 0.9982 - val_loss: 0.4784 - val_accuracy: 0.8865
Epoch 11/300
18/18 [==============================] - ETA: 0s - loss: 0.0154 - accuracy:
0.9982
Epoch 11: val_loss improved from 0.47835 to 0.47082, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 151ms/step - loss: 0.0154 -
accuracy: 0.9982 - val_loss: 0.4708 - val_accuracy: 0.8936
Epoch 12/300
18/18 [==============================] - ETA: 0s - loss: 0.0132 - accuracy:
1.0000
Epoch 12: val_loss did not improve from 0.47082
18/18 [==============================] - 3s 139ms/step - loss: 0.0132 -
accuracy: 1.0000 - val_loss: 0.4711 - val_accuracy: 0.8936
Epoch 13/300
18/18 [==============================] - ETA: 0s - loss: 0.0114 - accuracy:
1.0000
Epoch 13: val_loss improved from 0.47082 to 0.46821, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 162ms/step - loss: 0.0114 -
accuracy: 1.0000 - val_loss: 0.4682 - val_accuracy: 0.8936
Epoch 14/300
18/18 [==============================] - ETA: 0s - loss: 0.0100 - accuracy:
1.0000
Epoch 14: val_loss improved from 0.46821 to 0.46417, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 189ms/step - loss: 0.0100 -
accuracy: 1.0000 - val_loss: 0.4642 - val_accuracy: 0.8936
Epoch 15/300
18/18 [==============================] - ETA: 0s - loss: 0.0089 - accuracy:
1.0000
Epoch 15: val_loss improved from 0.46417 to 0.46311, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 159ms/step - loss: 0.0089 -
accuracy: 1.0000 - val_loss: 0.4631 - val_accuracy: 0.8936
Epoch 16/300
18/18 [==============================] - ETA: 0s - loss: 0.0082 - accuracy:
1.0000
Epoch 16: val_loss improved from 0.46311 to 0.45979, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 168ms/step - loss: 0.0082 -
accuracy: 1.0000 - val_loss: 0.4598 - val_accuracy: 0.8936
Epoch 17/300
18/18 [==============================] - ETA: 0s - loss: 0.0074 - accuracy:
1.0000
Epoch 17: val_loss did not improve from 0.45979
```

```
18/18 [==============================] - 3s 147ms/step - loss: 0.0074 -
accuracy: 1.0000 - val_loss: 0.4612 - val_accuracy: 0.8936
Epoch 18/300
18/18 [==============================] - ETA: 0s - loss: 0.0068 - accuracy:
1.0000
Epoch 18: val_loss did not improve from 0.45979
18/18 [==============================] - 3s 154ms/step - loss: 0.0068 -
accuracy: 1.0000 - val_loss: 0.4612 - val_accuracy: 0.8936
Epoch 19/300
18/18 [==============================] - ETA: 0s - loss: 0.0062 - accuracy:
1.0000
Epoch 19: val_loss improved from 0.45979 to 0.45787, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 159ms/step - loss: 0.0062 -
accuracy: 1.0000 - val_loss: 0.4579 - val_accuracy: 0.8936
Epoch 20/300
18/18 [==============================] - ETA: 0s - loss: 0.0058 - accuracy:
1.0000
Epoch 20: val_loss improved from 0.45787 to 0.45731, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 153ms/step - loss: 0.0058 -
accuracy: 1.0000 - val_loss: 0.4573 - val_accuracy: 0.8936
Epoch 21/300
18/18 [==============================] - ETA: 0s - loss: 0.0054 - accuracy:
1.0000
Epoch 21: val_loss did not improve from 0.45731
18/18 [==============================] - 3s 164ms/step - loss: 0.0054 -
accuracy: 1.0000 - val_loss: 0.4604 - val_accuracy: 0.8936
Epoch 22/300
18/18 [==============================] - ETA: 0s - loss: 0.0050 - accuracy:
1.0000
Epoch 22: val_loss improved from 0.45731 to 0.45279, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 155ms/step - loss: 0.0050 -
accuracy: 1.0000 - val_loss: 0.4528 - val_accuracy: 0.8936
Epoch 23/300
18/18 [==============================] - ETA: 0s - loss: 0.0047 - accuracy:
1.0000
Epoch 23: val_loss did not improve from 0.45279
18/18 [==============================] - 3s 157ms/step - loss: 0.0047 -
accuracy: 1.0000 - val_loss: 0.4616 - val_accuracy: 0.8936
Epoch 24/300
18/18 [==============================] - ETA: 0s - loss: 0.0044 - accuracy:
1.0000
Epoch 24: val_loss did not improve from 0.45279
18/18 [==============================] - 3s 153ms/step - loss: 0.0044 -
accuracy: 1.0000 - val_loss: 0.4545 - val_accuracy: 0.8936
Epoch 25/300
```

```
18/18 [==============================] - ETA: 0s - loss: 0.0041 - accuracy:
1.0000
Epoch 25: val_loss did not improve from 0.45279
18/18 [==============================] - 3s 155ms/step - loss: 0.0041 -
accuracy: 1.0000 - val_loss: 0.4535 - val_accuracy: 0.8936
Epoch 26/300
18/18 [==============================] - ETA: 0s - loss: 0.0039 - accuracy:
1.0000
Epoch 26: val_loss improved from 0.45279 to 0.44988, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 159ms/step - loss: 0.0039 -
accuracy: 1.0000 - val_loss: 0.4499 - val_accuracy: 0.8936
Epoch 27/300
18/18 [==============================] - ETA: 0s - loss: 0.0037 - accuracy:
1.0000
Epoch 27: val_loss did not improve from 0.44988
18/18 [==============================] - 3s 144ms/step - loss: 0.0037 -
accuracy: 1.0000 - val_loss: 0.4529 - val_accuracy: 0.8936
Epoch 28/300
18/18 [==============================] - ETA: 0s - loss: 0.0035 - accuracy:
1.0000
Epoch 28: val_loss did not improve from 0.44988
18/18 [==============================] - 3s 145ms/step - loss: 0.0035 -
accuracy: 1.0000 - val_loss: 0.4534 - val_accuracy: 0.8936
Epoch 29/300
18/18 [==============================] - ETA: 0s - loss: 0.0033 - accuracy:
1.0000
Epoch 29: val_loss improved from 0.44988 to 0.44985, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 148ms/step - loss: 0.0033 -
accuracy: 1.0000 - val_loss: 0.4499 - val_accuracy: 0.9007
Epoch 30/300
18/18 [==============================] - ETA: 0s - loss: 0.0031 - accuracy:
1.0000
Epoch 30: val_loss did not improve from 0.44985
18/18 [==============================] - 3s 153ms/step - loss: 0.0031 -
accuracy: 1.0000 - val_loss: 0.4514 - val_accuracy: 0.9007
Epoch 31/300
18/18 [==============================] - ETA: 0s - loss: 0.0030 - accuracy:
1.0000
Epoch 31: val_loss did not improve from 0.44985
18/18 [==============================] - 3s 148ms/step - loss: 0.0030 -
accuracy: 1.0000 - val_loss: 0.4540 - val_accuracy: 0.8936
Epoch 32/300
18/18 [==============================] - ETA: 0s - loss: 0.0028 - accuracy:
1.0000
Epoch 32: val_loss did not improve from 0.44985
18/18 [==============================] - 3s 145ms/step - loss: 0.0028 -
```

```
accuracy: 1.0000 - val_loss: 0.4502 - val_accuracy: 0.9007
Epoch 33/300
18/18 [==============================] - ETA: 0s - loss: 0.0027 - accuracy:
1.0000
Epoch 33: val_loss improved from 0.44985 to 0.44585, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 165ms/step - loss: 0.0027 -
accuracy: 1.0000 - val_loss: 0.4459 - val_accuracy: 0.9007
Epoch 34/300
18/18 [==============================] - ETA: 0s - loss: 0.0026 - accuracy:
1.0000
Epoch 34: val_loss did not improve from 0.44585
18/18 [==============================] - 3s 147ms/step - loss: 0.0026 -
accuracy: 1.0000 - val_loss: 0.4511 - val_accuracy: 0.9007
Epoch 35/300
18/18 [==============================] - ETA: 0s - loss: 0.0025 - accuracy:
1.0000
Epoch 35: val_loss did not improve from 0.44585
18/18 [==============================] - 3s 165ms/step - loss: 0.0025 -
accuracy: 1.0000 - val_loss: 0.4483 - val_accuracy: 0.9007
Epoch 36/300
18/18 [==============================] - ETA: 0s - loss: 0.0024 - accuracy:
1.0000
Epoch 36: val_loss did not improve from 0.44585
18/18 [==============================] - 3s 147ms/step - loss: 0.0024 -
accuracy: 1.0000 - val_loss: 0.4477 - val_accuracy: 0.9007
Epoch 37/300
18/18 [==============================] - ETA: 0s - loss: 0.0023 - accuracy:
1.0000
Epoch 37: val_loss did not improve from 0.44585
18/18 [==============================] - 3s 136ms/step - loss: 0.0023 -
accuracy: 1.0000 - val_loss: 0.4461 - val_accuracy: 0.9007
Epoch 38/300
18/18 [==============================] - ETA: 0s - loss: 0.0022 - accuracy:
1.0000
Epoch 38: val_loss did not improve from 0.44585
18/18 [==============================] - 3s 139ms/step - loss: 0.0022 -
accuracy: 1.0000 - val_loss: 0.4476 - val_accuracy: 0.9007
Epoch 39/300
18/18 [==============================] - ETA: 0s - loss: 0.0021 - accuracy:
1.0000
Epoch 39: val_loss did not improve from 0.44585
18/18 [==============================] - 3s 141ms/step - loss: 0.0021 -
accuracy: 1.0000 - val_loss: 0.4466 - val_accuracy: 0.9007
Epoch 40/300
18/18 [==============================] - ETA: 0s - loss: 0.0020 - accuracy:
1.0000
Epoch 40: val_loss did not improve from 0.44585
```

```
18/18 [==============================] - 3s 155ms/step - loss: 0.0020 -
accuracy: 1.0000 - val_loss: 0.4486 - val_accuracy: 0.9007
Epoch 41/300
18/18 [==============================] - ETA: 0s - loss: 0.0020 - accuracy:
1.0000
Epoch 41: val_loss improved from 0.44585 to 0.44534, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 165ms/step - loss: 0.0020 -
accuracy: 1.0000 - val_loss: 0.4453 - val_accuracy: 0.9078
Epoch 42/300
18/18 [==============================] - ETA: 0s - loss: 0.0019 - accuracy:
1.0000
Epoch 42: val_loss improved from 0.44534 to 0.44479, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 158ms/step - loss: 0.0019 -
accuracy: 1.0000 - val_loss: 0.4448 - val_accuracy: 0.9078
Epoch 43/300
18/18 [==============================] - ETA: 0s - loss: 0.0018 - accuracy:
1.0000
Epoch 43: val_loss did not improve from 0.44479
18/18 [==============================] - 3s 147ms/step - loss: 0.0018 -
accuracy: 1.0000 - val_loss: 0.4455 - val_accuracy: 0.9007
Epoch 44/300
18/18 [==============================] - ETA: 0s - loss: 0.0018 - accuracy:
1.0000
Epoch 44: val_loss did not improve from 0.44479
18/18 [==============================] - 3s 162ms/step - loss: 0.0018 -
accuracy: 1.0000 - val_loss: 0.4469 - val_accuracy: 0.9007
Epoch 45/300
18/18 [==============================] - ETA: 0s - loss: 0.0017 - accuracy:
1.0000
Epoch 45: val_loss improved from 0.44479 to 0.44353, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 150ms/step - loss: 0.0017 -
accuracy: 1.0000 - val_loss: 0.4435 - val_accuracy: 0.9078
Epoch 46/300
18/18 [==============================] - ETA: 0s - loss: 0.0016 - accuracy:
1.0000
Epoch 46: val_loss did not improve from 0.44353
18/18 [==============================] - 3s 147ms/step - loss: 0.0016 -
accuracy: 1.0000 - val_loss: 0.4452 - val_accuracy: 0.9078
Epoch 47/300
18/18 [==============================] - ETA: 0s - loss: 0.0016 - accuracy:
1.0000
Epoch 47: val_loss did not improve from 0.44353
18/18 [==============================] - 3s 152ms/step - loss: 0.0016 -
accuracy: 1.0000 - val_loss: 0.4440 - val_accuracy: 0.9078
Epoch 48/300
```

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18/18 [==============================] - ETA: 0s - loss: 0.0015 - accuracy:
1.0000
Epoch 48: val_loss improved from 0.44353 to 0.44200, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 169ms/step - loss: 0.0015 -
accuracy: 1.0000 - val_loss: 0.4420 - val_accuracy: 0.9078
Epoch 49/300
18/18 [==============================] - ETA: 0s - loss: 0.0015 - accuracy:
1.0000
Epoch 49: val_loss did not improve from 0.44200
18/18 [==============================] - 3s 140ms/step - loss: 0.0015 -
accuracy: 1.0000 - val_loss: 0.4433 - val_accuracy: 0.9078
Epoch 50/300
18/18 [==============================] - ETA: 0s - loss: 0.0014 - accuracy:
1.0000
Epoch 50: val_loss did not improve from 0.44200
18/18 [==============================] - 3s 160ms/step - loss: 0.0014 -
accuracy: 1.0000 - val_loss: 0.4439 - val_accuracy: 0.9078
Epoch 51/300
18/18 [==============================] - ETA: 0s - loss: 0.0014 - accuracy:
1.0000
Epoch 51: val_loss did not improve from 0.44200
18/18 [==============================] - 3s 154ms/step - loss: 0.0014 -
accuracy: 1.0000 - val_loss: 0.4452 - val_accuracy: 0.9078
Epoch 52/300
18/18 [==============================] - ETA: 0s - loss: 0.0013 - accuracy:
1.0000
Epoch 52: val_loss did not improve from 0.44200
18/18 [==============================] - 3s 138ms/step - loss: 0.0013 -
accuracy: 1.0000 - val_loss: 0.4455 - val_accuracy: 0.9078
Epoch 53/300
18/18 [==============================] - ETA: 0s - loss: 0.0013 - accuracy:
1.0000
Epoch 53: val_loss did not improve from 0.44200
18/18 [==============================] - 3s 144ms/step - loss: 0.0013 -
accuracy: 1.0000 - val_loss: 0.4431 - val_accuracy: 0.9078
Epoch 54/300
18/18 [==============================] - ETA: 0s - loss: 0.0013 - accuracy:
1.0000
Epoch 54: val_loss did not improve from 0.44200
18/18 [==============================] - 3s 160ms/step - loss: 0.0013 -
accuracy: 1.0000 - val_loss: 0.4467 - val_accuracy: 0.9078
Epoch 55/300
18/18 [==============================] - ETA: 0s - loss: 0.0012 - accuracy:
1.0000
Epoch 55: val_loss improved from 0.44200 to 0.44159, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 158ms/step - loss: 0.0012 -
```

```
accuracy: 1.0000 - val_loss: 0.4416 - val_accuracy: 0.9078
Epoch 56/300
18/18 [==============================] - ETA: 0s - loss: 0.0012 - accuracy:
1.0000
Epoch 56: val_loss did not improve from 0.44159
18/18 [==============================] - 3s 155ms/step - loss: 0.0012 -
accuracy: 1.0000 - val_loss: 0.4432 - val_accuracy: 0.9078
Epoch 57/300
18/18 [==============================] - ETA: 0s - loss: 0.0012 - accuracy:
1.0000
Epoch 57: val_loss did not improve from 0.44159
18/18 [==============================] - 3s 169ms/step - loss: 0.0012 -
accuracy: 1.0000 - val_loss: 0.4422 - val_accuracy: 0.9078
Epoch 58/300
18/18 [==============================] - ETA: 0s - loss: 0.0011 - accuracy:
1.0000
Epoch 58: val_loss did not improve from 0.44159
18/18 [==============================] - 3s 147ms/step - loss: 0.0011 -
accuracy: 1.0000 - val_loss: 0.4423 - val_accuracy: 0.9078
Epoch 59/300
18/18 [==============================] - ETA: 0s - loss: 0.0011 - accuracy:
1.0000
Epoch 59: val_loss did not improve from 0.44159
18/18 [==============================] - 3s 142ms/step - loss: 0.0011 -
accuracy: 1.0000 - val_loss: 0.4441 - val_accuracy: 0.9078
Epoch 60/300
18/18 [==============================] - ETA: 0s - loss: 0.0011 - accuracy:
1.0000
Epoch 60: val_loss did not improve from 0.44159
18/18 [==============================] - 3s 143ms/step - loss: 0.0011 -
accuracy: 1.0000 - val_loss: 0.4426 - val_accuracy: 0.9078
Epoch 61/300
18/18 [==============================] - ETA: 0s - loss: 0.0010 - accuracy:
1.0000
Epoch 61: val_loss did not improve from 0.44159
18/18 [==============================] - 3s 143ms/step - loss: 0.0010 -
accuracy: 1.0000 - val_loss: 0.4423 - val_accuracy: 0.9078
Epoch 62/300
18/18 [==============================] - ETA: 0s - loss: 0.0010 - accuracy:
1.0000
Epoch 62: val_loss did not improve from 0.44159
18/18 [==============================] - 3s 157ms/step - loss: 0.0010 -
accuracy: 1.0000 - val_loss: 0.4420 - val_accuracy: 0.9078
Epoch 63/300
18/18 [==============================] - ETA: 0s - loss: 9.9293e-04 - accuracy:
1.0000
Epoch 63: val_loss did not improve from 0.44159
18/18 [==============================] - 3s 139ms/step - loss: 9.9293e-04 -
```

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accuracy: 1.0000 - val_loss: 0.4434 - val_accuracy: 0.9078
Epoch 64/300
18/18 [==============================] - ETA: 0s - loss: 9.6731e-04 - accuracy:
1.0000
Epoch 64: val_loss did not improve from 0.44159
18/18 [==============================] - 3s 158ms/step - loss: 9.6731e-04 -
accuracy: 1.0000 - val_loss: 0.4427 - val_accuracy: 0.9078
Epoch 65/300
18/18 [==============================] - ETA: 0s - loss: 9.4200e-04 - accuracy:
1.0000
Epoch 65: val_loss improved from 0.44159 to 0.44128, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 158ms/step - loss: 9.4200e-04 -
accuracy: 1.0000 - val_loss: 0.4413 - val_accuracy: 0.9078
Epoch 66/300
18/18 [==============================] - ETA: 0s - loss: 9.2186e-04 - accuracy:
1.0000
Epoch 66: val_loss did not improve from 0.44128
18/18 [==============================] - 3s 161ms/step - loss: 9.2186e-04 -
accuracy: 1.0000 - val_loss: 0.4420 - val_accuracy: 0.9078
Epoch 67/300
18/18 [==============================] - ETA: 0s - loss: 9.0134e-04 - accuracy:
1.0000
Epoch 67: val_loss improved from 0.44128 to 0.44019, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 165ms/step - loss: 9.0134e-04 -
accuracy: 1.0000 - val_loss: 0.4402 - val_accuracy: 0.9078
Epoch 68/300
18/18 [==============================] - ETA: 0s - loss: 8.7603e-04 - accuracy:
1.0000
Epoch 68: val_loss did not improve from 0.44019
18/18 [==============================] - 3s 139ms/step - loss: 8.7603e-04 -
accuracy: 1.0000 - val_loss: 0.4436 - val_accuracy: 0.9078
Epoch 69/300
18/18 [==============================] - ETA: 0s - loss: 8.5711e-04 - accuracy:
1.0000
Epoch 69: val_loss did not improve from 0.44019
18/18 [==============================] - 3s 148ms/step - loss: 8.5711e-04 -
accuracy: 1.0000 - val_loss: 0.4417 - val_accuracy: 0.9078
Epoch 70/300
18/18 [==============================] - ETA: 0s - loss: 8.3574e-04 - accuracy:
1.0000
Epoch 70: val_loss did not improve from 0.44019
18/18 [==============================] - 3s 149ms/step - loss: 8.3574e-04 -
accuracy: 1.0000 - val_loss: 0.4422 - val_accuracy: 0.9078
Epoch 71/300
18/18 [==============================] - ETA: 0s - loss: 8.1571e-04 - accuracy:
1.0000
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Epoch 71: val_loss did not improve from 0.44019
18/18 [==============================] - 3s 155ms/step - loss: 8.1571e-04 -
accuracy: 1.0000 - val_loss: 0.4414 - val_accuracy: 0.9078
Epoch 72/300
18/18 [==============================] - ETA: 0s - loss: 7.9988e-04 - accuracy:
1.0000
Epoch 72: val_loss did not improve from 0.44019
18/18 [==============================] - 3s 146ms/step - loss: 7.9988e-04 -
accuracy: 1.0000 - val_loss: 0.4423 - val_accuracy: 0.9078
Epoch 73/300
18/18 [==============================] - ETA: 0s - loss: 7.8162e-04 - accuracy:
1.0000
Epoch 73: val_loss improved from 0.44019 to 0.43991, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 156ms/step - loss: 7.8162e-04 -
accuracy: 1.0000 - val_loss: 0.4399 - val_accuracy: 0.9078
Epoch 74/300
18/18 [==============================] - ETA: 0s - loss: 7.6298e-04 - accuracy:
1.0000
Epoch 74: val_loss did not improve from 0.43991
18/18 [==============================] - 3s 156ms/step - loss: 7.6298e-04 -
accuracy: 1.0000 - val_loss: 0.4400 - val_accuracy: 0.9078
Epoch 75/300
18/18 [==============================] - ETA: 0s - loss: 7.4595e-04 - accuracy:
1.0000
Epoch 75: val_loss did not improve from 0.43991
18/18 [==============================] - 3s 146ms/step - loss: 7.4595e-04 -
accuracy: 1.0000 - val_loss: 0.4427 - val_accuracy: 0.9078
Epoch 76/300
18/18 [==============================] - ETA: 0s - loss: 7.3023e-04 - accuracy:
1.0000
Epoch 76: val_loss did not improve from 0.43991
18/18 [==============================] - 3s 151ms/step - loss: 7.3023e-04 -
accuracy: 1.0000 - val_loss: 0.4416 - val_accuracy: 0.9078
Epoch 77/300
18/18 [==============================] - ETA: 0s - loss: 7.1324e-04 - accuracy:
1.0000
Epoch 77: val_loss improved from 0.43991 to 0.43969, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 158ms/step - loss: 7.1324e-04 -
accuracy: 1.0000 - val_loss: 0.4397 - val_accuracy: 0.9078
Epoch 78/300
18/18 [==============================] - ETA: 0s - loss: 7.0112e-04 - accuracy:
1.0000
Epoch 78: val_loss did not improve from 0.43969
18/18 [==============================] - 3s 153ms/step - loss: 7.0112e-04 -
accuracy: 1.0000 - val_loss: 0.4419 - val_accuracy: 0.9078
Epoch 79/300
```

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18/18 [==============================] - ETA: 0s - loss: 6.8392e-04 - accuracy:
1.0000
Epoch 79: val_loss did not improve from 0.43969
18/18 [==============================] - 3s 145ms/step - loss: 6.8392e-04 -
accuracy: 1.0000 - val_loss: 0.4409 - val_accuracy: 0.9078
Epoch 80/300
18/18 [==============================] - ETA: 0s - loss: 6.6949e-04 - accuracy:
1.0000
Epoch 80: val_loss improved from 0.43969 to 0.43880, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 148ms/step - loss: 6.6949e-04 -
accuracy: 1.0000 - val_loss: 0.4388 - val_accuracy: 0.9078
Epoch 81/300
18/18 [==============================] - ETA: 0s - loss: 6.5487e-04 - accuracy:
1.0000
Epoch 81: val_loss did not improve from 0.43880
18/18 [==============================] - 3s 143ms/step - loss: 6.5487e-04 -
accuracy: 1.0000 - val_loss: 0.4401 - val_accuracy: 0.9078
Epoch 82/300
18/18 [==============================] - ETA: 0s - loss: 6.4141e-04 - accuracy:
1.0000
Epoch 82: val_loss did not improve from 0.43880
18/18 [==============================] - 3s 143ms/step - loss: 6.4141e-04 -
accuracy: 1.0000 - val_loss: 0.4423 - val_accuracy: 0.9078
Epoch 83/300
18/18 [==============================] - ETA: 0s - loss: 6.2893e-04 - accuracy:
1.0000
Epoch 83: val_loss did not improve from 0.43880
18/18 [==============================] - 3s 148ms/step - loss: 6.2893e-04 -
accuracy: 1.0000 - val_loss: 0.4406 - val_accuracy: 0.9078
Epoch 84/300
18/18 [==============================] - ETA: 0s - loss: 6.1643e-04 - accuracy:
1.0000
Epoch 84: val_loss did not improve from 0.43880
18/18 [==============================] - 3s 145ms/step - loss: 6.1643e-04 -
accuracy: 1.0000 - val_loss: 0.4418 - val_accuracy: 0.9078
Epoch 85/300
18/18 [==============================] - ETA: 0s - loss: 6.0332e-04 - accuracy:
1.0000
Epoch 85: val_loss did not improve from 0.43880
18/18 [==============================] - 3s 139ms/step - loss: 6.0332e-04 -
accuracy: 1.0000 - val_loss: 0.4411 - val_accuracy: 0.9078
Epoch 86/300
18/18 [==============================] - ETA: 0s - loss: 5.9237e-04 - accuracy:
1.0000
Epoch 86: val_loss did not improve from 0.43880
18/18 [==============================] - 3s 144ms/step - loss: 5.9237e-04 -
accuracy: 1.0000 - val_loss: 0.4399 - val_accuracy: 0.9078
```

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Epoch 87/300
18/18 [==============================] - ETA: 0s - loss: 5.7990e-04 - accuracy:
1.0000
Epoch 87: val_loss did not improve from 0.43880
18/18 [==============================] - 3s 150ms/step - loss: 5.7990e-04 -
accuracy: 1.0000 - val_loss: 0.4398 - val_accuracy: 0.9078
Epoch 88/300
18/18 [==============================] - ETA: 0s - loss: 5.6883e-04 - accuracy:
1.0000
Epoch 88: val_loss did not improve from 0.43880
18/18 [==============================] - 3s 167ms/step - loss: 5.6883e-04 -
accuracy: 1.0000 - val_loss: 0.4400 - val_accuracy: 0.9078
Epoch 89/300
18/18 [==============================] - ETA: 0s - loss: 5.5812e-04 - accuracy:
1.0000
Epoch 89: val_loss did not improve from 0.43880
18/18 [==============================] - 3s 141ms/step - loss: 5.5812e-04 -
accuracy: 1.0000 - val_loss: 0.4408 - val_accuracy: 0.9078
Epoch 90/300
18/18 [==============================] - ETA: 0s - loss: 5.4794e-04 - accuracy:
1.0000
Epoch 90: val_loss improved from 0.43880 to 0.43872, saving model to
vgg16_custom.h5
18/18 [==============================] - 3s 168ms/step - loss: 5.4794e-04 -
accuracy: 1.0000 - val_loss: 0.4387 - val_accuracy: 0.9078
Epoch 91/300
18/18 [==============================] - ETA: 0s - loss: 5.3726e-04 - accuracy:
1.0000
Epoch 91: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 174ms/step - loss: 5.3726e-04 -
accuracy: 1.0000 - val_loss: 0.4409 - val_accuracy: 0.9078
Epoch 92/300
18/18 [==============================] - ETA: 0s - loss: 5.2681e-04 - accuracy:
1.0000
Epoch 92: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 144ms/step - loss: 5.2681e-04 -
accuracy: 1.0000 - val_loss: 0.4408 - val_accuracy: 0.9078
Epoch 93/300
18/18 [==============================] - ETA: 0s - loss: 5.1746e-04 - accuracy:
1.0000
Epoch 93: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 139ms/step - loss: 5.1746e-04 -
accuracy: 1.0000 - val_loss: 0.4408 - val_accuracy: 0.9078
Epoch 94/300
18/18 [==============================] - ETA: 0s - loss: 5.0793e-04 - accuracy:
1.0000
Epoch 94: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 136ms/step - loss: 5.0793e-04 -
```

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accuracy: 1.0000 - val_loss: 0.4389 - val_accuracy: 0.9078
Epoch 95/300
18/18 [==============================] - ETA: 0s - loss: 5.0056e-04 - accuracy:
1.0000
Epoch 95: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 153ms/step - loss: 5.0056e-04 -
accuracy: 1.0000 - val_loss: 0.4411 - val_accuracy: 0.9078
Epoch 96/300
18/18 [==============================] - ETA: 0s - loss: 4.8861e-04 - accuracy:
1.0000
Epoch 96: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 150ms/step - loss: 4.8861e-04 -
accuracy: 1.0000 - val_loss: 0.4401 - val_accuracy: 0.9078
Epoch 97/300
18/18 [==============================] - ETA: 0s - loss: 4.7984e-04 - accuracy:
1.0000
Epoch 97: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 152ms/step - loss: 4.7984e-04 -
accuracy: 1.0000 - val_loss: 0.4396 - val_accuracy: 0.9078
Epoch 98/300
18/18 [==============================] - ETA: 0s - loss: 4.7178e-04 - accuracy:
1.0000
Epoch 98: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 170ms/step - loss: 4.7178e-04 -
accuracy: 1.0000 - val_loss: 0.4390 - val_accuracy: 0.9078
Epoch 99/300
18/18 [==============================] - ETA: 0s - loss: 4.6273e-04 - accuracy:
1.0000
Epoch 99: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 145ms/step - loss: 4.6273e-04 -
accuracy: 1.0000 - val_loss: 0.4397 - val_accuracy: 0.9078
Epoch 100/300
18/18 [==============================] - ETA: 0s - loss: 4.5503e-04 - accuracy:
1.0000
Epoch 100: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 148ms/step - loss: 4.5503e-04 -
accuracy: 1.0000 - val_loss: 0.4405 - val_accuracy: 0.9078
Epoch 101/300
18/18 [==============================] - ETA: 0s - loss: 4.4726e-04 - accuracy:
1.0000
Epoch 101: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 142ms/step - loss: 4.4726e-04 -
accuracy: 1.0000 - val_loss: 0.4420 - val_accuracy: 0.9078
Epoch 102/300
18/18 [==============================] - ETA: 0s - loss: 4.3957e-04 - accuracy:
1.0000
Epoch 102: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 144ms/step - loss: 4.3957e-04 -
```

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accuracy: 1.0000 - val_loss: 0.4407 - val_accuracy: 0.9078
Epoch 103/300
18/18 [==============================] - ETA: 0s - loss: 4.3124e-04 - accuracy:
1.0000
Epoch 103: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 141ms/step - loss: 4.3124e-04 -
accuracy: 1.0000 - val_loss: 0.4405 - val_accuracy: 0.9078
Epoch 104/300
18/18 [==============================] - ETA: 0s - loss: 4.2439e-04 - accuracy:
1.0000
Epoch 104: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 140ms/step - loss: 4.2439e-04 -
accuracy: 1.0000 - val_loss: 0.4413 - val_accuracy: 0.9078
Epoch 105/300
18/18 [==============================] - ETA: 0s - loss: 4.1644e-04 - accuracy:
1.0000
Epoch 105: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 144ms/step - loss: 4.1644e-04 -
accuracy: 1.0000 - val_loss: 0.4402 - val_accuracy: 0.9078
Epoch 106/300
18/18 [==============================] - ETA: 0s - loss: 4.0926e-04 - accuracy:
1.0000
Epoch 106: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 135ms/step - loss: 4.0926e-04 -
accuracy: 1.0000 - val_loss: 0.4394 - val_accuracy: 0.9078
Epoch 107/300
18/18 [==============================] - ETA: 0s - loss: 4.0285e-04 - accuracy:
1.0000
Epoch 107: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 147ms/step - loss: 4.0285e-04 -
accuracy: 1.0000 - val_loss: 0.4402 - val_accuracy: 0.9078
Epoch 108/300
18/18 [==============================] - ETA: 0s - loss: 3.9577e-04 - accuracy:
1.0000
Epoch 108: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 158ms/step - loss: 3.9577e-04 -
accuracy: 1.0000 - val_loss: 0.4394 - val_accuracy: 0.9078
Epoch 109/300
18/18 [==============================] - ETA: 0s - loss: 3.8965e-04 - accuracy:
1.0000
Epoch 109: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 147ms/step - loss: 3.8965e-04 -
accuracy: 1.0000 - val_loss: 0.4403 - val_accuracy: 0.9078
Epoch 110/300
18/18 [==============================] - ETA: 0s - loss: 3.8310e-04 - accuracy:
1.0000
Epoch 110: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 154ms/step - loss: 3.8310e-04 -
```

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accuracy: 1.0000 - val_loss: 0.4406 - val_accuracy: 0.9078
Epoch 111/300
18/18 [==============================] - ETA: 0s - loss: 3.7715e-04 - accuracy:
1.0000
Epoch 111: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 146ms/step - loss: 3.7715e-04 -
accuracy: 1.0000 - val_loss: 0.4401 - val_accuracy: 0.9078
Epoch 112/300
18/18 [==============================] - ETA: 0s - loss: 3.7086e-04 - accuracy:
1.0000
Epoch 112: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 157ms/step - loss: 3.7086e-04 -
accuracy: 1.0000 - val_loss: 0.4395 - val_accuracy: 0.9078
Epoch 113/300
18/18 [==============================] - ETA: 0s - loss: 3.6446e-04 - accuracy:
1.0000
Epoch 113: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 157ms/step - loss: 3.6446e-04 -
accuracy: 1.0000 - val_loss: 0.4396 - val_accuracy: 0.9078
Epoch 114/300
18/18 [==============================] - ETA: 0s - loss: 3.5908e-04 - accuracy:
1.0000
Epoch 114: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 150ms/step - loss: 3.5908e-04 -
accuracy: 1.0000 - val_loss: 0.4408 - val_accuracy: 0.9078
Epoch 115/300
18/18 [==============================] - ETA: 0s - loss: 3.5270e-04 - accuracy:
1.0000
Epoch 115: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 145ms/step - loss: 3.5270e-04 -
accuracy: 1.0000 - val_loss: 0.4396 - val_accuracy: 0.9078
Epoch 116/300
18/18 [==============================] - ETA: 0s - loss: 3.4699e-04 - accuracy:
1.0000
Epoch 116: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 149ms/step - loss: 3.4699e-04 -
accuracy: 1.0000 - val_loss: 0.4398 - val_accuracy: 0.9078
Epoch 117/300
18/18 [==============================] - ETA: 0s - loss: 3.4178e-04 - accuracy:
1.0000
Epoch 117: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 147ms/step - loss: 3.4178e-04 -
accuracy: 1.0000 - val_loss: 0.4401 - val_accuracy: 0.9078
Epoch 118/300
18/18 [==============================] - ETA: 0s - loss: 3.3642e-04 - accuracy:
1.0000
Epoch 118: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 162ms/step - loss: 3.3642e-04 -
```

```
accuracy: 1.0000 - val_loss: 0.4398 - val_accuracy: 0.9078
Epoch 119/300
18/18 [==============================] - ETA: 0s - loss: 3.3118e-04 - accuracy:
1.0000
Epoch 119: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 138ms/step - loss: 3.3118e-04 -
accuracy: 1.0000 - val_loss: 0.4402 - val_accuracy: 0.9078
Epoch 120/300
18/18 [==============================] - ETA: 0s - loss: 3.2597e-04 - accuracy:
1.0000
Epoch 120: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 170ms/step - loss: 3.2597e-04 -
accuracy: 1.0000 - val_loss: 0.4404 - val_accuracy: 0.9078
Epoch 121/300
18/18 [==============================] - ETA: 0s - loss: 3.2139e-04 - accuracy:
1.0000
Epoch 121: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 140ms/step - loss: 3.2139e-04 -
accuracy: 1.0000 - val_loss: 0.4396 - val_accuracy: 0.9078
Epoch 122/300
18/18 [==============================] - ETA: 0s - loss: 3.1636e-04 - accuracy:
1.0000
Epoch 122: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 141ms/step - loss: 3.1636e-04 -
accuracy: 1.0000 - val_loss: 0.4405 - val_accuracy: 0.9078
Epoch 123/300
18/18 [==============================] - ETA: 0s - loss: 3.1114e-04 - accuracy:
1.0000
Epoch 123: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 148ms/step - loss: 3.1114e-04 -
accuracy: 1.0000 - val_loss: 0.4406 - val_accuracy: 0.9078
Epoch 124/300
18/18 [==============================] - ETA: 0s - loss: 3.0669e-04 - accuracy:
1.0000
Epoch 124: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 144ms/step - loss: 3.0669e-04 -
accuracy: 1.0000 - val_loss: 0.4394 - val_accuracy: 0.9078
Epoch 125/300
18/18 [==============================] - ETA: 0s - loss: 3.0182e-04 - accuracy:
1.0000
Epoch 125: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 145ms/step - loss: 3.0182e-04 -
accuracy: 1.0000 - val_loss: 0.4403 - val_accuracy: 0.9078
Epoch 126/300
18/18 [==============================] - ETA: 0s - loss: 2.9746e-04 - accuracy:
1.0000
Epoch 126: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 143ms/step - loss: 2.9746e-04 -
```

```
accuracy: 1.0000 - val_loss: 0.4394 - val_accuracy: 0.9078
Epoch 127/300
18/18 [==============================] - ETA: 0s - loss: 2.9338e-04 - accuracy:
1.0000
Epoch 127: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 151ms/step - loss: 2.9338e-04 -
accuracy: 1.0000 - val_loss: 0.4404 - val_accuracy: 0.9078
Epoch 128/300
18/18 [==============================] - ETA: 0s - loss: 2.8856e-04 - accuracy:
1.0000
Epoch 128: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 140ms/step - loss: 2.8856e-04 -
accuracy: 1.0000 - val_loss: 0.4404 - val_accuracy: 0.9078
Epoch 129/300
18/18 [==============================] - ETA: 0s - loss: 2.8423e-04 - accuracy:
1.0000
Epoch 129: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 146ms/step - loss: 2.8423e-04 -
accuracy: 1.0000 - val_loss: 0.4406 - val_accuracy: 0.9078
Epoch 130/300
18/18 [==============================] - ETA: 0s - loss: 2.7994e-04 - accuracy:
1.0000
Epoch 130: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 150ms/step - loss: 2.7994e-04 -
accuracy: 1.0000 - val_loss: 0.4401 - val_accuracy: 0.9078
Epoch 131/300
18/18 [==============================] - ETA: 0s - loss: 2.7597e-04 - accuracy:
1.0000
Epoch 131: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 142ms/step - loss: 2.7597e-04 -
accuracy: 1.0000 - val_loss: 0.4405 - val_accuracy: 0.9078
Epoch 132/300
18/18 [==============================] - ETA: 0s - loss: 2.7174e-04 - accuracy:
1.0000
Epoch 132: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 152ms/step - loss: 2.7174e-04 -
accuracy: 1.0000 - val_loss: 0.4398 - val_accuracy: 0.9078
Epoch 133/300
18/18 [==============================] - ETA: 0s - loss: 2.6808e-04 - accuracy:
1.0000
Epoch 133: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 149ms/step - loss: 2.6808e-04 -
accuracy: 1.0000 - val_loss: 0.4397 - val_accuracy: 0.9078
Epoch 134/300
18/18 [==============================] - ETA: 0s - loss: 2.6396e-04 - accuracy:
1.0000
Epoch 134: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 147ms/step - loss: 2.6396e-04 -
```

```
accuracy: 1.0000 - val_loss: 0.4405 - val_accuracy: 0.9078
Epoch 135/300
18/18 [==============================] - ETA: 0s - loss: 2.6050e-04 - accuracy:
1.0000
Epoch 135: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 149ms/step - loss: 2.6050e-04 -
accuracy: 1.0000 - val_loss: 0.4399 - val_accuracy: 0.9078
Epoch 136/300
18/18 [==============================] - ETA: 0s - loss: 2.5674e-04 - accuracy:
1.0000
Epoch 136: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 142ms/step - loss: 2.5674e-04 -
accuracy: 1.0000 - val_loss: 0.4400 - val_accuracy: 0.9078
Epoch 137/300
18/18 [==============================] - ETA: 0s - loss: 2.5322e-04 - accuracy:
1.0000
Epoch 137: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 143ms/step - loss: 2.5322e-04 -
accuracy: 1.0000 - val_loss: 0.4393 - val_accuracy: 0.9078
Epoch 138/300
18/18 [==============================] - ETA: 0s - loss: 2.4955e-04 - accuracy:
1.0000
Epoch 138: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 169ms/step - loss: 2.4955e-04 -
accuracy: 1.0000 - val_loss: 0.4396 - val_accuracy: 0.9078
Epoch 139/300
18/18 [==============================] - ETA: 0s - loss: 2.4583e-04 - accuracy:
1.0000
Epoch 139: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 172ms/step - loss: 2.4583e-04 -
accuracy: 1.0000 - val_loss: 0.4401 - val_accuracy: 0.9078
Epoch 140/300
18/18 [==============================] - ETA: 0s - loss: 2.4251e-04 - accuracy:
1.0000
Epoch 140: val_loss did not improve from 0.43872
Restoring model weights from the end of the best epoch: 90.
18/18 [==============================] - 3s 150ms/step - loss: 2.4251e-04 -
accuracy: 1.0000 - val_loss: 0.4408 - val_accuracy: 0.9078
Epoch 140: early stopping
```

Evaluamos la pérdida global y el acurracy

[ ]:
```
loss, accuracy = model1.evaluate(test_generator, verbose=1)
print(f"Pérdida global: {loss:.4f}")
print(f"Precisión global (accuracy): {accuracy:.4f}")
```

```
5/5 [==============================] - 1s 121ms/step - loss: 0.4387 - accuracy:
0.9078
Pérdida global: 0.4387
```

```
Precisión global (accuracy): 0.9078
```

La precisión global en el conjunto de test es alta, 0,9. Mientras que la pérdida es algo alta 0,4

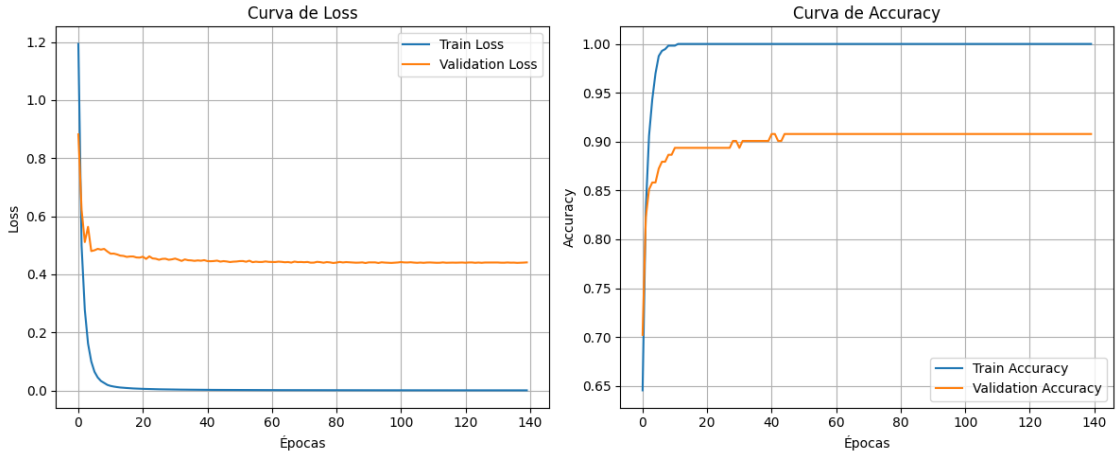
Gráficamos las curvas de loss y acurracy, comparamos los resultados de la red en los conjuntos de entrenamiento y validación

[ ]:
```python
# Guardamos el historial
history_dict = history.history

# Curvas de pérdida
plt.figure(figsize=(12, 5))
plt.subplot(1, 2, 1)
plt.plot(history_dict['loss'], label='Train Loss')
plt.plot(history_dict['val_loss'], label='Validation Loss')
plt.title('Curva de Loss')
plt.xlabel('Épocas')
plt.ylabel('Loss')
plt.legend()
plt.grid(True)

# Curvas de precisión
plt.subplot(1, 2, 2)
plt.plot(history_dict['accuracy'], label='Train Accuracy')
plt.plot(history_dict['val_accuracy'], label='Validation Accuracy')
plt.title('Curva de Accuracy')
plt.xlabel('Épocas')
plt.ylabel('Accuracy')
plt.legend()
plt.grid(True)

plt.tight_layout()
plt.show()
```



Viendo las gráficas parece que el modelo aprende muy rápido en el conjunto de entrenamiento (con loss cercana a cero y accuracy perfecta). Sin embargo, el rendimiento sobre el conjunto de validación se estabiliza pronto, sugeriendo que la red puede no estar aprendiendo de la mejor forma. También parece que la red sufre sobreajuste casi desde un primer momento.

Me parece interesante comentar también el evidente desfase entre las el loss, entorno al 0.4, y el accuracy, 0.9. Esto puede estar evidenciando que el modelo acierta pero con poca seguridad.

Utilizamos una matriz de confusión y vemos sus métricas

[ ]:
```
# Obtener predicciones
y_pred_prob = model1.predict(test_generator, verbose=1)
y_pred = (y_pred_prob > 0.5).astype(int).reshape(-1)  # binarizamos

# Etiquetas reales
y_true = test_generator.classes

# Matriz de confusión
conf_mat = confusion_matrix(y_true, y_pred)

# Informe de clasificación (Precision, Recall, F1)
print(" Classification Report:\n")
print(classification_report(y_true, y_pred, target_names=test_generator.
  ↪class_indices.keys()))

# AUC
auc = roc_auc_score(y_true, y_pred_prob)
print(f" AUC Score: {auc:.4f}")

# Dibujar matriz de confusión
plt.figure(figsize=(5, 4))
sns.heatmap(conf_mat, annot=True, fmt='d', cmap='Blues',
            xticklabels=test_generator.class_indices.keys(),
            yticklabels=test_generator.class_indices.keys())
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```

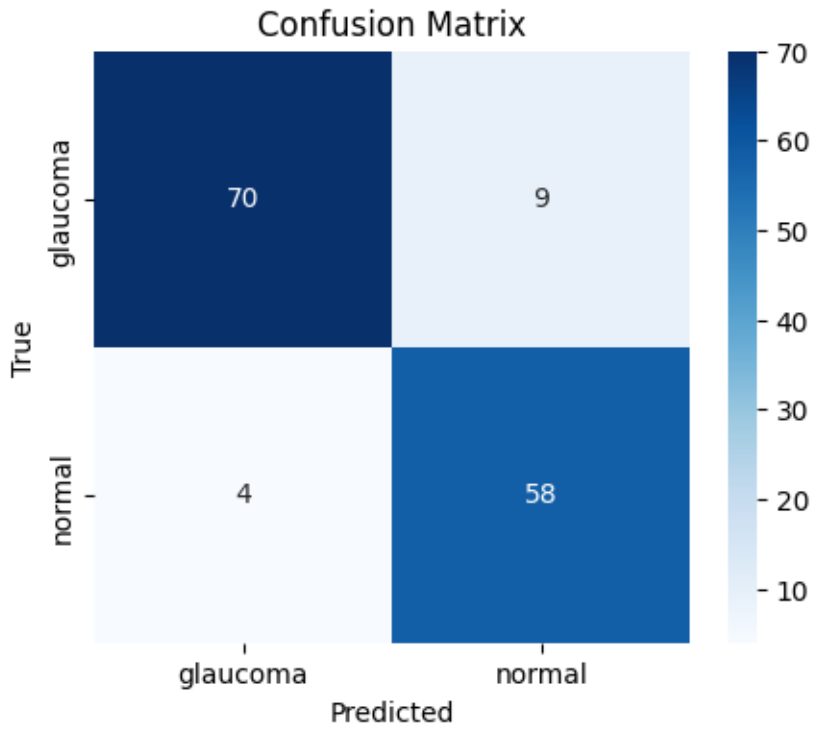
```
5/5 [==============================] - 1s 131ms/step
 Classification Report:

              precision    recall  f1-score   support

    glaucoma       0.95      0.89      0.92        79
      normal       0.87      0.94      0.90        62
```

```
    accuracy                           0.91       141
   macro avg       0.91      0.91      0.91       141
weighted avg       0.91      0.91      0.91       141

AUC Score: 0.9559
```



En general, las métricas son muy buenas, todas cercanas al 90%. Aunque en un caso médico como este me parece que deberían ser mejores ya que tanto la precisión para los casos normales y el recall para el glaucoma deberían superar ampliamente el 90% de acierto. Imaginemos que una persona sufre un falso positivo de glaucoma y se somete a terapias con muchos efectos secundarios o que son caras. Lo mismo en el otro sentido, si una persona es un falso negativo en glaucoma puede ser una situación de riesgo, ya que la una detención tardía puede causarle problemas mayores.

2 2. Transferencia de aprendizaje

2.1 2.1. Utilizar transferencia de aprendizaje para crear la nueva red VGG16-glaucoma congelando todas las capas convolucionales de VGG16 y entrenando la nueva red con las imágenes de ACRIMA; obtener y aportar descripción gráfica de la red resultante, curvas de aprendizaje y un índice de su rendimiento en ACRIMA.

Creamos la nueva red VGG16-glaucoma

[ ]:
```
vgg16_glaucoma = VGG16(weights='imagenet', include_top=False, input_shape=(224,␣
↪224, 3))
for layer in vgg16_glaucoma.layers:
    layer.trainable = False

# Nueva cabeza binaria
x = Flatten()(vgg16_glaucoma.output)
x = Dense(1024, activation='relu')(x)
x = Dense(256, activation='relu')(x)
x = Dropout(0.5)(x)
output = Dense(1, activation='sigmoid')(x)

model2 = Model(inputs=vgg16_glaucoma.input, outputs=output)
model2.compile(optimizer=Adam(1e-6), loss='binary_crossentropy',␣
↪metrics=['accuracy'])
```

Procedemos a entrenarla

[ ]:
```
history1 = model2.fit(
    train_generator,
    epochs=300,
    validation_data=test_generator,
    callbacks=[checkpoint, early])
```

```
Epoch 1/300
18/18 [==============================] - ETA: 0s - loss: 2.6072 - accuracy:
0.4894
Epoch 1: val_loss did not improve from 0.43872
18/18 [==============================] - 6s 194ms/step - loss: 2.6072 -
accuracy: 0.4894 - val_loss: 1.1637 - val_accuracy: 0.5745
Epoch 2/300
18/18 [==============================] - ETA: 0s - loss: 2.2999 - accuracy:
0.5284
Epoch 2: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 176ms/step - loss: 2.2999 -
accuracy: 0.5284 - val_loss: 0.9008 - val_accuracy: 0.6596
Epoch 3/300
18/18 [==============================] - ETA: 0s - loss: 2.1991 - accuracy:
0.5284
Epoch 3: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 160ms/step - loss: 2.1991 -
accuracy: 0.5284 - val_loss: 0.7821 - val_accuracy: 0.6879
Epoch 4/300
18/18 [==============================] - ETA: 0s - loss: 1.7548 - accuracy:
0.6135
Epoch 4: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 181ms/step - loss: 1.7548 -
accuracy: 0.6135 - val_loss: 0.6984 - val_accuracy: 0.7376
```

```
Epoch 5/300
18/18 [==============================] - ETA: 0s - loss: 1.4329 - accuracy:
0.6401
Epoch 5: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 156ms/step - loss: 1.4329 -
accuracy: 0.6401 - val_loss: 0.6358 - val_accuracy: 0.7589
Epoch 6/300
18/18 [==============================] - ETA: 0s - loss: 1.5947 - accuracy:
0.6418
Epoch 6: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 159ms/step - loss: 1.5947 -
accuracy: 0.6418 - val_loss: 0.5962 - val_accuracy: 0.7660
Epoch 7/300
18/18 [==============================] - ETA: 0s - loss: 1.3429 - accuracy:
0.6613
Epoch 7: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 154ms/step - loss: 1.3429 -
accuracy: 0.6613 - val_loss: 0.5616 - val_accuracy: 0.7660
Epoch 8/300
18/18 [==============================] - ETA: 0s - loss: 1.3578 - accuracy:
0.6631
Epoch 8: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 157ms/step - loss: 1.3578 -
accuracy: 0.6631 - val_loss: 0.5243 - val_accuracy: 0.7872
Epoch 9/300
18/18 [==============================] - ETA: 0s - loss: 1.1542 - accuracy:
0.6968
Epoch 9: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 170ms/step - loss: 1.1542 -
accuracy: 0.6968 - val_loss: 0.4979 - val_accuracy: 0.7943
Epoch 10/300
18/18 [==============================] - ETA: 0s - loss: 1.2328 - accuracy:
0.6791
Epoch 10: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 179ms/step - loss: 1.2328 -
accuracy: 0.6791 - val_loss: 0.4629 - val_accuracy: 0.8156
Epoch 11/300
18/18 [==============================] - ETA: 0s - loss: 1.0915 - accuracy:
0.7110
Epoch 11: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 152ms/step - loss: 1.0915 -
accuracy: 0.7110 - val_loss: 0.4503 - val_accuracy: 0.8227
Epoch 12/300
18/18 [==============================] - ETA: 0s - loss: 0.9824 - accuracy:
0.7323
Epoch 12: val_loss did not improve from 0.43872
18/18 [==============================] - 3s 174ms/step - loss: 0.9824 -
accuracy: 0.7323 - val_loss: 0.4539 - val_accuracy: 0.8156
```

```
Epoch 13/300
18/18 [==============================] - ETA: 0s - loss: 0.9380 - accuracy:
0.7145
Epoch 13: val_loss improved from 0.43872 to 0.43524, saving model to
vgg16_custom.h5

/usr/local/lib/python3.11/dist-packages/keras/src/engine/training.py:3103:
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')`.
  saving_api.save_model(

18/18 [==============================] - 4s 198ms/step - loss: 0.9380 -
accuracy: 0.7145 - val_loss: 0.4352 - val_accuracy: 0.8156
Epoch 14/300
18/18 [==============================] - ETA: 0s - loss: 0.8919 - accuracy:
0.7305
Epoch 14: val_loss improved from 0.43524 to 0.41720, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 203ms/step - loss: 0.8919 -
accuracy: 0.7305 - val_loss: 0.4172 - val_accuracy: 0.8440
Epoch 15/300
18/18 [==============================] - ETA: 0s - loss: 0.8166 - accuracy:
0.7376
Epoch 15: val_loss improved from 0.41720 to 0.41061, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 205ms/step - loss: 0.8166 -
accuracy: 0.7376 - val_loss: 0.4106 - val_accuracy: 0.8369
Epoch 16/300
18/18 [==============================] - ETA: 0s - loss: 0.8105 - accuracy:
0.7606
Epoch 16: val_loss improved from 0.41061 to 0.38386, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 199ms/step - loss: 0.8105 -
accuracy: 0.7606 - val_loss: 0.3839 - val_accuracy: 0.8511
Epoch 17/300
18/18 [==============================] - ETA: 0s - loss: 0.7229 - accuracy:
0.7801
Epoch 17: val_loss improved from 0.38386 to 0.37478, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 201ms/step - loss: 0.7229 -
accuracy: 0.7801 - val_loss: 0.3748 - val_accuracy: 0.8511
Epoch 18/300
18/18 [==============================] - ETA: 0s - loss: 0.6951 - accuracy:
0.8103
Epoch 18: val_loss did not improve from 0.37478
18/18 [==============================] - 3s 148ms/step - loss: 0.6951 -
accuracy: 0.8103 - val_loss: 0.3805 - val_accuracy: 0.8511
Epoch 19/300
```

```
18/18 [==============================] - ETA: 0s - loss: 0.6885 - accuracy:
0.7872
Epoch 19: val_loss improved from 0.37478 to 0.37149, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 216ms/step - loss: 0.6885 -
accuracy: 0.7872 - val_loss: 0.3715 - val_accuracy: 0.8511
Epoch 20/300
18/18 [==============================] - ETA: 0s - loss: 0.6236 - accuracy:
0.8298
Epoch 20: val_loss improved from 0.37149 to 0.35747, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 199ms/step - loss: 0.6236 -
accuracy: 0.8298 - val_loss: 0.3575 - val_accuracy: 0.8582
Epoch 21/300
18/18 [==============================] - ETA: 0s - loss: 0.5836 - accuracy:
0.8262
Epoch 21: val_loss improved from 0.35747 to 0.35039, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 219ms/step - loss: 0.5836 -
accuracy: 0.8262 - val_loss: 0.3504 - val_accuracy: 0.8582
Epoch 22/300
18/18 [==============================] - ETA: 0s - loss: 0.4392 - accuracy:
0.8511
Epoch 22: val_loss improved from 0.35039 to 0.34584, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 234ms/step - loss: 0.4392 -
accuracy: 0.8511 - val_loss: 0.3458 - val_accuracy: 0.8511
Epoch 23/300
18/18 [==============================] - ETA: 0s - loss: 0.5667 - accuracy:
0.8245
Epoch 23: val_loss did not improve from 0.34584
18/18 [==============================] - 3s 161ms/step - loss: 0.5667 -
accuracy: 0.8245 - val_loss: 0.3498 - val_accuracy: 0.8511
Epoch 24/300
18/18 [==============================] - ETA: 0s - loss: 0.4808 - accuracy:
0.8670
Epoch 24: val_loss improved from 0.34584 to 0.34159, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 205ms/step - loss: 0.4808 -
accuracy: 0.8670 - val_loss: 0.3416 - val_accuracy: 0.8511
Epoch 25/300
18/18 [==============================] - ETA: 0s - loss: 0.4730 - accuracy:
0.8617
Epoch 25: val_loss improved from 0.34159 to 0.33001, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 205ms/step - loss: 0.4730 -
accuracy: 0.8617 - val_loss: 0.3300 - val_accuracy: 0.8582
Epoch 26/300
```

```
18/18 [==============================] - ETA: 0s - loss: 0.4399 - accuracy:
0.8387
Epoch 26: val_loss improved from 0.33001 to 0.32246, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 201ms/step - loss: 0.4399 -
accuracy: 0.8387 - val_loss: 0.3225 - val_accuracy: 0.8652
Epoch 27/300
18/18 [==============================] - ETA: 0s - loss: 0.4243 - accuracy:
0.8546
Epoch 27: val_loss improved from 0.32246 to 0.31804, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 201ms/step - loss: 0.4243 -
accuracy: 0.8546 - val_loss: 0.3180 - val_accuracy: 0.8652
Epoch 28/300
18/18 [==============================] - ETA: 0s - loss: 0.3872 - accuracy:
0.8706
Epoch 28: val_loss improved from 0.31804 to 0.31075, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 204ms/step - loss: 0.3872 -
accuracy: 0.8706 - val_loss: 0.3108 - val_accuracy: 0.8652
Epoch 29/300
18/18 [==============================] - ETA: 0s - loss: 0.3867 - accuracy:
0.8599
Epoch 29: val_loss did not improve from 0.31075
18/18 [==============================] - 3s 146ms/step - loss: 0.3867 -
accuracy: 0.8599 - val_loss: 0.3159 - val_accuracy: 0.8723
Epoch 30/300
18/18 [==============================] - ETA: 0s - loss: 0.2821 - accuracy:
0.8936
Epoch 30: val_loss improved from 0.31075 to 0.31071, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 214ms/step - loss: 0.2821 -
accuracy: 0.8936 - val_loss: 0.3107 - val_accuracy: 0.8652
Epoch 31/300
18/18 [==============================] - ETA: 0s - loss: 0.3940 - accuracy:
0.8794
Epoch 31: val_loss improved from 0.31071 to 0.30416, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 217ms/step - loss: 0.3940 -
accuracy: 0.8794 - val_loss: 0.3042 - val_accuracy: 0.8652
Epoch 32/300
18/18 [==============================] - ETA: 0s - loss: 0.3999 - accuracy:
0.8652
Epoch 32: val_loss improved from 0.30416 to 0.30213, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 209ms/step - loss: 0.3999 -
accuracy: 0.8652 - val_loss: 0.3021 - val_accuracy: 0.8652
Epoch 33/300
```

```
18/18 [==============================] - ETA: 0s - loss: 0.3453 - accuracy:
0.8759
Epoch 33: val_loss did not improve from 0.30213
18/18 [==============================] - 3s 146ms/step - loss: 0.3453 -
accuracy: 0.8759 - val_loss: 0.3054 - val_accuracy: 0.8723
Epoch 34/300
18/18 [==============================] - ETA: 0s - loss: 0.3418 - accuracy:
0.8688
Epoch 34: val_loss improved from 0.30213 to 0.29714, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 206ms/step - loss: 0.3418 -
accuracy: 0.8688 - val_loss: 0.2971 - val_accuracy: 0.8723
Epoch 35/300
18/18 [==============================] - ETA: 0s - loss: 0.3232 - accuracy:
0.8741
Epoch 35: val_loss did not improve from 0.29714
18/18 [==============================] - 3s 161ms/step - loss: 0.3232 -
accuracy: 0.8741 - val_loss: 0.2982 - val_accuracy: 0.8723
Epoch 36/300
18/18 [==============================] - ETA: 0s - loss: 0.3174 - accuracy:
0.8954
Epoch 36: val_loss did not improve from 0.29714
18/18 [==============================] - 3s 151ms/step - loss: 0.3174 -
accuracy: 0.8954 - val_loss: 0.2989 - val_accuracy: 0.8723
Epoch 37/300
18/18 [==============================] - ETA: 0s - loss: 0.2405 - accuracy:
0.9007
Epoch 37: val_loss did not improve from 0.29714
18/18 [==============================] - 3s 165ms/step - loss: 0.2405 -
accuracy: 0.9007 - val_loss: 0.3100 - val_accuracy: 0.8652
Epoch 38/300
18/18 [==============================] - ETA: 0s - loss: 0.2840 - accuracy:
0.8936
Epoch 38: val_loss did not improve from 0.29714
18/18 [==============================] - 3s 149ms/step - loss: 0.2840 -
accuracy: 0.8936 - val_loss: 0.3088 - val_accuracy: 0.8652
Epoch 39/300
18/18 [==============================] - ETA: 0s - loss: 0.1994 - accuracy:
0.9220
Epoch 39: val_loss did not improve from 0.29714
18/18 [==============================] - 3s 149ms/step - loss: 0.1994 -
accuracy: 0.9220 - val_loss: 0.3026 - val_accuracy: 0.8652
Epoch 40/300
18/18 [==============================] - ETA: 0s - loss: 0.2614 - accuracy:
0.8972
Epoch 40: val_loss improved from 0.29714 to 0.28451, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 215ms/step - loss: 0.2614 -
```

```
accuracy: 0.8972 - val_loss: 0.2845 - val_accuracy: 0.8794
Epoch 41/300
18/18 [==============================] - ETA: 0s - loss: 0.2858 - accuracy:
0.8954
Epoch 41: val_loss improved from 0.28451 to 0.27716, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 220ms/step - loss: 0.2858 -
accuracy: 0.8954 - val_loss: 0.2772 - val_accuracy: 0.8723
Epoch 42/300
18/18 [==============================] - ETA: 0s - loss: 0.2336 - accuracy:
0.9113
Epoch 42: val_loss improved from 0.27716 to 0.27322, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 198ms/step - loss: 0.2336 -
accuracy: 0.9113 - val_loss: 0.2732 - val_accuracy: 0.8865
Epoch 43/300
18/18 [==============================] - ETA: 0s - loss: 0.2240 - accuracy:
0.9220
Epoch 43: val_loss did not improve from 0.27322
18/18 [==============================] - 3s 147ms/step - loss: 0.2240 -
accuracy: 0.9220 - val_loss: 0.2744 - val_accuracy: 0.8794
Epoch 44/300
18/18 [==============================] - ETA: 0s - loss: 0.2678 - accuracy:
0.9113
Epoch 44: val_loss did not improve from 0.27322
18/18 [==============================] - 3s 146ms/step - loss: 0.2678 -
accuracy: 0.9113 - val_loss: 0.2742 - val_accuracy: 0.8723
Epoch 45/300
18/18 [==============================] - ETA: 0s - loss: 0.1949 - accuracy:
0.9238
Epoch 45: val_loss did not improve from 0.27322
18/18 [==============================] - 3s 150ms/step - loss: 0.1949 -
accuracy: 0.9238 - val_loss: 0.2776 - val_accuracy: 0.8794
Epoch 46/300
18/18 [==============================] - ETA: 0s - loss: 0.1878 - accuracy:
0.9379
Epoch 46: val_loss did not improve from 0.27322
18/18 [==============================] - 3s 151ms/step - loss: 0.1878 -
accuracy: 0.9379 - val_loss: 0.2788 - val_accuracy: 0.8794
Epoch 47/300
18/18 [==============================] - ETA: 0s - loss: 0.2137 - accuracy:
0.9220
Epoch 47: val_loss did not improve from 0.27322
18/18 [==============================] - 3s 166ms/step - loss: 0.2137 -
accuracy: 0.9220 - val_loss: 0.2805 - val_accuracy: 0.8794
Epoch 48/300
18/18 [==============================] - ETA: 0s - loss: 0.1746 - accuracy:
0.9291
```

```
Epoch 48: val_loss did not improve from 0.27322
18/18 [==============================] - 3s 144ms/step - loss: 0.1746 -
accuracy: 0.9291 - val_loss: 0.2832 - val_accuracy: 0.8794
Epoch 49/300
18/18 [==============================] - ETA: 0s - loss: 0.2054 - accuracy:
0.9326
Epoch 49: val_loss did not improve from 0.27322
18/18 [==============================] - 3s 157ms/step - loss: 0.2054 -
accuracy: 0.9326 - val_loss: 0.2777 - val_accuracy: 0.8794
Epoch 50/300
18/18 [==============================] - ETA: 0s - loss: 0.1539 - accuracy:
0.9326
Epoch 50: val_loss did not improve from 0.27322
18/18 [==============================] - 3s 145ms/step - loss: 0.1539 -
accuracy: 0.9326 - val_loss: 0.2779 - val_accuracy: 0.8794
Epoch 51/300
18/18 [==============================] - ETA: 0s - loss: 0.1544 - accuracy:
0.9468
Epoch 51: val_loss improved from 0.27322 to 0.27262, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 200ms/step - loss: 0.1544 -
accuracy: 0.9468 - val_loss: 0.2726 - val_accuracy: 0.8794
Epoch 52/300
18/18 [==============================] - ETA: 0s - loss: 0.1656 - accuracy:
0.9433
Epoch 52: val_loss improved from 0.27262 to 0.26823, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 201ms/step - loss: 0.1656 -
accuracy: 0.9433 - val_loss: 0.2682 - val_accuracy: 0.8794
Epoch 53/300
18/18 [==============================] - ETA: 0s - loss: 0.1892 - accuracy:
0.9379
Epoch 53: val_loss did not improve from 0.26823
18/18 [==============================] - 3s 140ms/step - loss: 0.1892 -
accuracy: 0.9379 - val_loss: 0.2707 - val_accuracy: 0.8794
Epoch 54/300
18/18 [==============================] - ETA: 0s - loss: 0.1825 - accuracy:
0.9415
Epoch 54: val_loss improved from 0.26823 to 0.26454, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 207ms/step - loss: 0.1825 -
accuracy: 0.9415 - val_loss: 0.2645 - val_accuracy: 0.8865
Epoch 55/300
18/18 [==============================] - ETA: 0s - loss: 0.1353 - accuracy:
0.9344
Epoch 55: val_loss improved from 0.26454 to 0.26104, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 209ms/step - loss: 0.1353 -
```

```
accuracy: 0.9344 - val_loss: 0.2610 - val_accuracy: 0.9007
Epoch 56/300
18/18 [==============================] - ETA: 0s - loss: 0.1461 - accuracy:
0.9344
Epoch 56: val_loss improved from 0.26104 to 0.25694, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 215ms/step - loss: 0.1461 -
accuracy: 0.9344 - val_loss: 0.2569 - val_accuracy: 0.9078
Epoch 57/300
18/18 [==============================] - ETA: 0s - loss: 0.1862 - accuracy:
0.9291
Epoch 57: val_loss did not improve from 0.25694
18/18 [==============================] - 3s 145ms/step - loss: 0.1862 -
accuracy: 0.9291 - val_loss: 0.2594 - val_accuracy: 0.9007
Epoch 58/300
18/18 [==============================] - ETA: 0s - loss: 0.1065 - accuracy:
0.9628
Epoch 58: val_loss did not improve from 0.25694
18/18 [==============================] - 3s 150ms/step - loss: 0.1065 -
accuracy: 0.9628 - val_loss: 0.2617 - val_accuracy: 0.8936
Epoch 59/300
18/18 [==============================] - ETA: 0s - loss: 0.1622 - accuracy:
0.9521
Epoch 59: val_loss did not improve from 0.25694
18/18 [==============================] - 3s 167ms/step - loss: 0.1622 -
accuracy: 0.9521 - val_loss: 0.2615 - val_accuracy: 0.8936
Epoch 60/300
18/18 [==============================] - ETA: 0s - loss: 0.1316 - accuracy:
0.9468
Epoch 60: val_loss did not improve from 0.25694
18/18 [==============================] - 3s 155ms/step - loss: 0.1316 -
accuracy: 0.9468 - val_loss: 0.2586 - val_accuracy: 0.9007
Epoch 61/300
18/18 [==============================] - ETA: 0s - loss: 0.1046 - accuracy:
0.9628
Epoch 61: val_loss improved from 0.25694 to 0.25530, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 212ms/step - loss: 0.1046 -
accuracy: 0.9628 - val_loss: 0.2553 - val_accuracy: 0.9007
Epoch 62/300
18/18 [==============================] - ETA: 0s - loss: 0.1228 - accuracy:
0.9628
Epoch 62: val_loss improved from 0.25530 to 0.25067, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 199ms/step - loss: 0.1228 -
accuracy: 0.9628 - val_loss: 0.2507 - val_accuracy: 0.9078
Epoch 63/300
18/18 [==============================] - ETA: 0s - loss: 0.0917 - accuracy:
```

```
0.9645
Epoch 63: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 139ms/step - loss: 0.0917 -
accuracy: 0.9645 - val_loss: 0.2528 - val_accuracy: 0.9078
Epoch 64/300
18/18 [==============================] - ETA: 0s - loss: 0.1244 - accuracy:
0.9574
Epoch 64: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 155ms/step - loss: 0.1244 -
accuracy: 0.9574 - val_loss: 0.2537 - val_accuracy: 0.9007
Epoch 65/300
18/18 [==============================] - ETA: 0s - loss: 0.1410 - accuracy:
0.9397
Epoch 65: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 181ms/step - loss: 0.1410 -
accuracy: 0.9397 - val_loss: 0.2601 - val_accuracy: 0.9007
Epoch 66/300
18/18 [==============================] - ETA: 0s - loss: 0.0719 - accuracy:
0.9752
Epoch 66: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 143ms/step - loss: 0.0719 -
accuracy: 0.9752 - val_loss: 0.2605 - val_accuracy: 0.9007
Epoch 67/300
18/18 [==============================] - ETA: 0s - loss: 0.1180 - accuracy:
0.9610
Epoch 67: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 153ms/step - loss: 0.1180 -
accuracy: 0.9610 - val_loss: 0.2592 - val_accuracy: 0.9007
Epoch 68/300
18/18 [==============================] - ETA: 0s - loss: 0.1091 - accuracy:
0.9663
Epoch 68: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 142ms/step - loss: 0.1091 -
accuracy: 0.9663 - val_loss: 0.2564 - val_accuracy: 0.9007
Epoch 69/300
18/18 [==============================] - ETA: 0s - loss: 0.0985 - accuracy:
0.9645
Epoch 69: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 158ms/step - loss: 0.0985 -
accuracy: 0.9645 - val_loss: 0.2548 - val_accuracy: 0.9007
Epoch 70/300
18/18 [==============================] - ETA: 0s - loss: 0.1427 - accuracy:
0.9433
Epoch 70: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 154ms/step - loss: 0.1427 -
accuracy: 0.9433 - val_loss: 0.2532 - val_accuracy: 0.9007
Epoch 71/300
18/18 [==============================] - ETA: 0s - loss: 0.0776 - accuracy:
```

```
0.9734
Epoch 71: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 142ms/step - loss: 0.0776 -
accuracy: 0.9734 - val_loss: 0.2566 - val_accuracy: 0.9007
Epoch 72/300
18/18 [==============================] - ETA: 0s - loss: 0.0867 - accuracy:
0.9752
Epoch 72: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 155ms/step - loss: 0.0867 -
accuracy: 0.9752 - val_loss: 0.2589 - val_accuracy: 0.9078
Epoch 73/300
18/18 [==============================] - ETA: 0s - loss: 0.0772 - accuracy:
0.9752
Epoch 73: val_loss did not improve from 0.25067
18/18 [==============================] - 3s 163ms/step - loss: 0.0772 -
accuracy: 0.9752 - val_loss: 0.2545 - val_accuracy: 0.9007
Epoch 74/300
18/18 [==============================] - ETA: 0s - loss: 0.1228 - accuracy:
0.9574
Epoch 74: val_loss improved from 0.25067 to 0.24971, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 217ms/step - loss: 0.1228 -
accuracy: 0.9574 - val_loss: 0.2497 - val_accuracy: 0.9078
Epoch 75/300
18/18 [==============================] - ETA: 0s - loss: 0.1048 - accuracy:
0.9663
Epoch 75: val_loss improved from 0.24971 to 0.24906, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 217ms/step - loss: 0.1048 -
accuracy: 0.9663 - val_loss: 0.2491 - val_accuracy: 0.9078
Epoch 76/300
18/18 [==============================] - ETA: 0s - loss: 0.1127 - accuracy:
0.9628
Epoch 76: val_loss did not improve from 0.24906
18/18 [==============================] - 3s 147ms/step - loss: 0.1127 -
accuracy: 0.9628 - val_loss: 0.2491 - val_accuracy: 0.9078
Epoch 77/300
18/18 [==============================] - ETA: 0s - loss: 0.0781 - accuracy:
0.9663
Epoch 77: val_loss improved from 0.24906 to 0.24721, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 203ms/step - loss: 0.0781 -
accuracy: 0.9663 - val_loss: 0.2472 - val_accuracy: 0.9078
Epoch 78/300
18/18 [==============================] - ETA: 0s - loss: 0.0788 - accuracy:
0.9699
Epoch 78: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 145ms/step - loss: 0.0788 -
```

```
accuracy: 0.9699 - val_loss: 0.2490 - val_accuracy: 0.9149
Epoch 79/300
18/18 [==============================] - ETA: 0s - loss: 0.0617 - accuracy:
0.9734
Epoch 79: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 145ms/step - loss: 0.0617 -
accuracy: 0.9734 - val_loss: 0.2479 - val_accuracy: 0.9149
Epoch 80/300
18/18 [==============================] - ETA: 0s - loss: 0.0986 - accuracy:
0.9628
Epoch 80: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 144ms/step - loss: 0.0986 -
accuracy: 0.9628 - val_loss: 0.2489 - val_accuracy: 0.9149
Epoch 81/300
18/18 [==============================] - ETA: 0s - loss: 0.0564 - accuracy:
0.9787
Epoch 81: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 160ms/step - loss: 0.0564 -
accuracy: 0.9787 - val_loss: 0.2481 - val_accuracy: 0.9149
Epoch 82/300
18/18 [==============================] - ETA: 0s - loss: 0.0519 - accuracy:
0.9876
Epoch 82: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 149ms/step - loss: 0.0519 -
accuracy: 0.9876 - val_loss: 0.2486 - val_accuracy: 0.9149
Epoch 83/300
18/18 [==============================] - ETA: 0s - loss: 0.0969 - accuracy:
0.9663
Epoch 83: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 144ms/step - loss: 0.0969 -
accuracy: 0.9663 - val_loss: 0.2490 - val_accuracy: 0.9149
Epoch 84/300
18/18 [==============================] - ETA: 0s - loss: 0.0664 - accuracy:
0.9752
Epoch 84: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 141ms/step - loss: 0.0664 -
accuracy: 0.9752 - val_loss: 0.2499 - val_accuracy: 0.9078
Epoch 85/300
18/18 [==============================] - ETA: 0s - loss: 0.0797 - accuracy:
0.9716
Epoch 85: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 145ms/step - loss: 0.0797 -
accuracy: 0.9716 - val_loss: 0.2504 - val_accuracy: 0.9149
Epoch 86/300
18/18 [==============================] - ETA: 0s - loss: 0.0618 - accuracy:
0.9699
Epoch 86: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 155ms/step - loss: 0.0618 -
```

```
accuracy: 0.9699 - val_loss: 0.2519 - val_accuracy: 0.9149
Epoch 87/300
18/18 [==============================] - ETA: 0s - loss: 0.0850 - accuracy:
0.9681
Epoch 87: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 168ms/step - loss: 0.0850 -
accuracy: 0.9681 - val_loss: 0.2511 - val_accuracy: 0.9149
Epoch 88/300
18/18 [==============================] - ETA: 0s - loss: 0.0817 - accuracy:
0.9645
Epoch 88: val_loss did not improve from 0.24721
18/18 [==============================] - 3s 146ms/step - loss: 0.0817 -
accuracy: 0.9645 - val_loss: 0.2483 - val_accuracy: 0.9220
Epoch 89/300
18/18 [==============================] - ETA: 0s - loss: 0.0500 - accuracy:
0.9840
Epoch 89: val_loss improved from 0.24721 to 0.24708, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 209ms/step - loss: 0.0500 -
accuracy: 0.9840 - val_loss: 0.2471 - val_accuracy: 0.9220
Epoch 90/300
18/18 [==============================] - ETA: 0s - loss: 0.0651 - accuracy:
0.9752
Epoch 90: val_loss did not improve from 0.24708
18/18 [==============================] - 3s 153ms/step - loss: 0.0651 -
accuracy: 0.9752 - val_loss: 0.2495 - val_accuracy: 0.9149
Epoch 91/300
18/18 [==============================] - ETA: 0s - loss: 0.0682 - accuracy:
0.9699
Epoch 91: val_loss did not improve from 0.24708
18/18 [==============================] - 3s 147ms/step - loss: 0.0682 -
accuracy: 0.9699 - val_loss: 0.2521 - val_accuracy: 0.9149
Epoch 92/300
18/18 [==============================] - ETA: 0s - loss: 0.0719 - accuracy:
0.9787
Epoch 92: val_loss did not improve from 0.24708
18/18 [==============================] - 3s 154ms/step - loss: 0.0719 -
accuracy: 0.9787 - val_loss: 0.2485 - val_accuracy: 0.9220
Epoch 93/300
18/18 [==============================] - ETA: 0s - loss: 0.0398 - accuracy:
0.9894
Epoch 93: val_loss improved from 0.24708 to 0.24459, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 213ms/step - loss: 0.0398 -
accuracy: 0.9894 - val_loss: 0.2446 - val_accuracy: 0.9220
Epoch 94/300
18/18 [==============================] - ETA: 0s - loss: 0.0548 - accuracy:
0.9734
```

```
Epoch 94: val_loss did not improve from 0.24459
18/18 [==============================] - 3s 151ms/step - loss: 0.0548 -
accuracy: 0.9734 - val_loss: 0.2477 - val_accuracy: 0.9220
Epoch 95/300
18/18 [==============================] - ETA: 0s - loss: 0.0399 - accuracy:
0.9858
Epoch 95: val_loss did not improve from 0.24459
18/18 [==============================] - 3s 156ms/step - loss: 0.0399 -
accuracy: 0.9858 - val_loss: 0.2499 - val_accuracy: 0.9149
Epoch 96/300
18/18 [==============================] - ETA: 0s - loss: 0.0675 - accuracy:
0.9716
Epoch 96: val_loss did not improve from 0.24459
18/18 [==============================] - 3s 157ms/step - loss: 0.0675 -
accuracy: 0.9716 - val_loss: 0.2533 - val_accuracy: 0.9149
Epoch 97/300
18/18 [==============================] - ETA: 0s - loss: 0.0599 - accuracy:
0.9770
Epoch 97: val_loss did not improve from 0.24459
18/18 [==============================] - 3s 153ms/step - loss: 0.0599 -
accuracy: 0.9770 - val_loss: 0.2516 - val_accuracy: 0.9149
Epoch 98/300
18/18 [==============================] - ETA: 0s - loss: 0.0347 - accuracy:
0.9805
Epoch 98: val_loss did not improve from 0.24459
18/18 [==============================] - 3s 153ms/step - loss: 0.0347 -
accuracy: 0.9805 - val_loss: 0.2476 - val_accuracy: 0.9220
Epoch 99/300
18/18 [==============================] - ETA: 0s - loss: 0.0412 - accuracy:
0.9840
Epoch 99: val_loss did not improve from 0.24459
18/18 [==============================] - 3s 151ms/step - loss: 0.0412 -
accuracy: 0.9840 - val_loss: 0.2462 - val_accuracy: 0.9220
Epoch 100/300
18/18 [==============================] - ETA: 0s - loss: 0.0447 - accuracy:
0.9823
Epoch 100: val_loss did not improve from 0.24459
18/18 [==============================] - 3s 148ms/step - loss: 0.0447 -
accuracy: 0.9823 - val_loss: 0.2449 - val_accuracy: 0.9149
Epoch 101/300
18/18 [==============================] - ETA: 0s - loss: 0.0525 - accuracy:
0.9752
Epoch 101: val_loss improved from 0.24459 to 0.24294, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 212ms/step - loss: 0.0525 -
accuracy: 0.9752 - val_loss: 0.2429 - val_accuracy: 0.9149
Epoch 102/300
18/18 [==============================] - ETA: 0s - loss: 0.0348 - accuracy:
```

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0.9876
Epoch 102: val_loss improved from 0.24294 to 0.24235, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 212ms/step - loss: 0.0348 -
accuracy: 0.9876 - val_loss: 0.2423 - val_accuracy: 0.9220
Epoch 103/300
18/18 [==============================] - ETA: 0s - loss: 0.0572 - accuracy:
0.9770
Epoch 103: val_loss did not improve from 0.24235
18/18 [==============================] - 3s 151ms/step - loss: 0.0572 -
accuracy: 0.9770 - val_loss: 0.2475 - val_accuracy: 0.9220
Epoch 104/300
18/18 [==============================] - ETA: 0s - loss: 0.0577 - accuracy:
0.9770
Epoch 104: val_loss did not improve from 0.24235
18/18 [==============================] - 3s 153ms/step - loss: 0.0577 -
accuracy: 0.9770 - val_loss: 0.2439 - val_accuracy: 0.9220
Epoch 105/300
18/18 [==============================] - ETA: 0s - loss: 0.0689 - accuracy:
0.9752
Epoch 105: val_loss improved from 0.24235 to 0.23966, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 221ms/step - loss: 0.0689 -
accuracy: 0.9752 - val_loss: 0.2397 - val_accuracy: 0.9220
Epoch 106/300
18/18 [==============================] - ETA: 0s - loss: 0.0582 - accuracy:
0.9840
Epoch 106: val_loss improved from 0.23966 to 0.23826, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 202ms/step - loss: 0.0582 -
accuracy: 0.9840 - val_loss: 0.2383 - val_accuracy: 0.9220
Epoch 107/300
18/18 [==============================] - ETA: 0s - loss: 0.0705 - accuracy:
0.9663
Epoch 107: val_loss improved from 0.23826 to 0.23676, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 199ms/step - loss: 0.0705 -
accuracy: 0.9663 - val_loss: 0.2368 - val_accuracy: 0.9220
Epoch 108/300
18/18 [==============================] - ETA: 0s - loss: 0.0550 - accuracy:
0.9876
Epoch 108: val_loss did not improve from 0.23676
18/18 [==============================] - 3s 147ms/step - loss: 0.0550 -
accuracy: 0.9876 - val_loss: 0.2371 - val_accuracy: 0.9220
Epoch 109/300
18/18 [==============================] - ETA: 0s - loss: 0.0656 - accuracy:
0.9734
Epoch 109: val_loss did not improve from 0.23676
```

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18/18 [==============================] - 3s 146ms/step - loss: 0.0656 -
accuracy: 0.9734 - val_loss: 0.2397 - val_accuracy: 0.9220
Epoch 110/300
18/18 [==============================] - ETA: 0s - loss: 0.0516 - accuracy:
0.9858
Epoch 110: val_loss did not improve from 0.23676
18/18 [==============================] - 3s 149ms/step - loss: 0.0516 -
accuracy: 0.9858 - val_loss: 0.2387 - val_accuracy: 0.9220
Epoch 111/300
18/18 [==============================] - ETA: 0s - loss: 0.0417 - accuracy:
0.9823
Epoch 111: val_loss improved from 0.23676 to 0.23638, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 206ms/step - loss: 0.0417 -
accuracy: 0.9823 - val_loss: 0.2364 - val_accuracy: 0.9220
Epoch 112/300
18/18 [==============================] - ETA: 0s - loss: 0.0342 - accuracy:
0.9876
Epoch 112: val_loss improved from 0.23638 to 0.23392, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 212ms/step - loss: 0.0342 -
accuracy: 0.9876 - val_loss: 0.2339 - val_accuracy: 0.9220
Epoch 113/300
18/18 [==============================] - ETA: 0s - loss: 0.0362 - accuracy:
0.9876
Epoch 113: val_loss improved from 0.23392 to 0.23260, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 207ms/step - loss: 0.0362 -
accuracy: 0.9876 - val_loss: 0.2326 - val_accuracy: 0.9220
Epoch 114/300
18/18 [==============================] - ETA: 0s - loss: 0.0428 - accuracy:
0.9823
Epoch 114: val_loss did not improve from 0.23260
18/18 [==============================] - 3s 177ms/step - loss: 0.0428 -
accuracy: 0.9823 - val_loss: 0.2344 - val_accuracy: 0.9220
Epoch 115/300
18/18 [==============================] - ETA: 0s - loss: 0.0244 - accuracy:
0.9894
Epoch 115: val_loss improved from 0.23260 to 0.23259, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 225ms/step - loss: 0.0244 -
accuracy: 0.9894 - val_loss: 0.2326 - val_accuracy: 0.9220
Epoch 116/300
18/18 [==============================] - ETA: 0s - loss: 0.0445 - accuracy:
0.9840
Epoch 116: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 154ms/step - loss: 0.0445 -
accuracy: 0.9840 - val_loss: 0.2345 - val_accuracy: 0.9220
```

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Epoch 117/300
18/18 [==============================] - ETA: 0s - loss: 0.0580 - accuracy:
0.9734
Epoch 117: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 153ms/step - loss: 0.0580 -
accuracy: 0.9734 - val_loss: 0.2383 - val_accuracy: 0.9220
Epoch 118/300
18/18 [==============================] - ETA: 0s - loss: 0.0410 - accuracy:
0.9787
Epoch 118: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 161ms/step - loss: 0.0410 -
accuracy: 0.9787 - val_loss: 0.2363 - val_accuracy: 0.9220
Epoch 119/300
18/18 [==============================] - ETA: 0s - loss: 0.0430 - accuracy:
0.9840
Epoch 119: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 164ms/step - loss: 0.0430 -
accuracy: 0.9840 - val_loss: 0.2356 - val_accuracy: 0.9220
Epoch 120/300
18/18 [==============================] - ETA: 0s - loss: 0.0327 - accuracy:
0.9911
Epoch 120: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 153ms/step - loss: 0.0327 -
accuracy: 0.9911 - val_loss: 0.2375 - val_accuracy: 0.9220
Epoch 121/300
18/18 [==============================] - ETA: 0s - loss: 0.0416 - accuracy:
0.9823
Epoch 121: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 152ms/step - loss: 0.0416 -
accuracy: 0.9823 - val_loss: 0.2347 - val_accuracy: 0.9220
Epoch 122/300
18/18 [==============================] - ETA: 0s - loss: 0.0404 - accuracy:
0.9823
Epoch 122: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 151ms/step - loss: 0.0404 -
accuracy: 0.9823 - val_loss: 0.2326 - val_accuracy: 0.9220
Epoch 123/300
18/18 [==============================] - ETA: 0s - loss: 0.0415 - accuracy:
0.9840
Epoch 123: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 154ms/step - loss: 0.0415 -
accuracy: 0.9840 - val_loss: 0.2344 - val_accuracy: 0.9220
Epoch 124/300
18/18 [==============================] - ETA: 0s - loss: 0.0247 - accuracy:
0.9911
Epoch 124: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 153ms/step - loss: 0.0247 -
accuracy: 0.9911 - val_loss: 0.2347 - val_accuracy: 0.9220
```

```
Epoch 125/300
18/18 [==============================] - ETA: 0s - loss: 0.0391 - accuracy:
0.9894
Epoch 125: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 148ms/step - loss: 0.0391 -
accuracy: 0.9894 - val_loss: 0.2359 - val_accuracy: 0.9220
Epoch 126/300
18/18 [==============================] - ETA: 0s - loss: 0.0184 - accuracy:
0.9947
Epoch 126: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 145ms/step - loss: 0.0184 -
accuracy: 0.9947 - val_loss: 0.2357 - val_accuracy: 0.9220
Epoch 127/300
18/18 [==============================] - ETA: 0s - loss: 0.0225 - accuracy:
0.9929
Epoch 127: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 147ms/step - loss: 0.0225 -
accuracy: 0.9929 - val_loss: 0.2359 - val_accuracy: 0.9220
Epoch 128/300
18/18 [==============================] - ETA: 0s - loss: 0.0254 - accuracy:
0.9894
Epoch 128: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 147ms/step - loss: 0.0254 -
accuracy: 0.9894 - val_loss: 0.2347 - val_accuracy: 0.9220
Epoch 129/300
18/18 [==============================] - ETA: 0s - loss: 0.0316 - accuracy:
0.9840
Epoch 129: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 189ms/step - loss: 0.0316 -
accuracy: 0.9840 - val_loss: 0.2342 - val_accuracy: 0.9220
Epoch 130/300
18/18 [==============================] - ETA: 0s - loss: 0.0178 - accuracy:
0.9947
Epoch 130: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 142ms/step - loss: 0.0178 -
accuracy: 0.9947 - val_loss: 0.2353 - val_accuracy: 0.9220
Epoch 131/300
18/18 [==============================] - ETA: 0s - loss: 0.0328 - accuracy:
0.9911
Epoch 131: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 145ms/step - loss: 0.0328 -
accuracy: 0.9911 - val_loss: 0.2349 - val_accuracy: 0.9220
Epoch 132/300
18/18 [==============================] - ETA: 0s - loss: 0.0309 - accuracy:
0.9876
Epoch 132: val_loss did not improve from 0.23259
18/18 [==============================] - 3s 153ms/step - loss: 0.0309 -
accuracy: 0.9876 - val_loss: 0.2348 - val_accuracy: 0.9220
```

```
Epoch 133/300
18/18 [==============================] - ETA: 0s - loss: 0.0397 - accuracy:
0.9858
Epoch 133: val_loss improved from 0.23259 to 0.23190, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 201ms/step - loss: 0.0397 -
accuracy: 0.9858 - val_loss: 0.2319 - val_accuracy: 0.9220
Epoch 134/300
18/18 [==============================] - ETA: 0s - loss: 0.0409 - accuracy:
0.9840
Epoch 134: val_loss did not improve from 0.23190
18/18 [==============================] - 3s 160ms/step - loss: 0.0409 -
accuracy: 0.9840 - val_loss: 0.2332 - val_accuracy: 0.9220
Epoch 135/300
18/18 [==============================] - ETA: 0s - loss: 0.0216 - accuracy:
0.9947
Epoch 135: val_loss did not improve from 0.23190
18/18 [==============================] - 3s 153ms/step - loss: 0.0216 -
accuracy: 0.9947 - val_loss: 0.2356 - val_accuracy: 0.9220
Epoch 136/300
18/18 [==============================] - ETA: 0s - loss: 0.0230 - accuracy:
0.9929
Epoch 136: val_loss did not improve from 0.23190
18/18 [==============================] - 3s 151ms/step - loss: 0.0230 -
accuracy: 0.9929 - val_loss: 0.2397 - val_accuracy: 0.9220
Epoch 137/300
18/18 [==============================] - ETA: 0s - loss: 0.0151 - accuracy:
0.9947
Epoch 137: val_loss did not improve from 0.23190
18/18 [==============================] - 3s 151ms/step - loss: 0.0151 -
accuracy: 0.9947 - val_loss: 0.2380 - val_accuracy: 0.9220
Epoch 138/300
18/18 [==============================] - ETA: 0s - loss: 0.0262 - accuracy:
0.9911
Epoch 138: val_loss did not improve from 0.23190
18/18 [==============================] - 3s 146ms/step - loss: 0.0262 -
accuracy: 0.9911 - val_loss: 0.2346 - val_accuracy: 0.9220
Epoch 139/300
18/18 [==============================] - ETA: 0s - loss: 0.0238 - accuracy:
0.9876
Epoch 139: val_loss improved from 0.23190 to 0.23169, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 210ms/step - loss: 0.0238 -
accuracy: 0.9876 - val_loss: 0.2317 - val_accuracy: 0.9220
Epoch 140/300
18/18 [==============================] - ETA: 0s - loss: 0.0353 - accuracy:
0.9858
Epoch 140: val_loss improved from 0.23169 to 0.23167, saving model to
```

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vgg16_custom.h5
18/18 [==============================] - 4s 237ms/step - loss: 0.0353 -
accuracy: 0.9858 - val_loss: 0.2317 - val_accuracy: 0.9220
Epoch 141/300
18/18 [==============================] - ETA: 0s - loss: 0.0350 - accuracy:
0.9876
Epoch 141: val_loss improved from 0.23167 to 0.23119, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 222ms/step - loss: 0.0350 -
accuracy: 0.9876 - val_loss: 0.2312 - val_accuracy: 0.9220
Epoch 142/300
18/18 [==============================] - ETA: 0s - loss: 0.0294 - accuracy:
0.9876
Epoch 142: val_loss improved from 0.23119 to 0.23053, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 232ms/step - loss: 0.0294 -
accuracy: 0.9876 - val_loss: 0.2305 - val_accuracy: 0.9220
Epoch 143/300
18/18 [==============================] - ETA: 0s - loss: 0.0309 - accuracy:
0.9929
Epoch 143: val_loss improved from 0.23053 to 0.22994, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 206ms/step - loss: 0.0309 -
accuracy: 0.9929 - val_loss: 0.2299 - val_accuracy: 0.9220
Epoch 144/300
18/18 [==============================] - ETA: 0s - loss: 0.0304 - accuracy:
0.9911
Epoch 144: val_loss did not improve from 0.22994
18/18 [==============================] - 3s 155ms/step - loss: 0.0304 -
accuracy: 0.9911 - val_loss: 0.2302 - val_accuracy: 0.9220
Epoch 145/300
18/18 [==============================] - ETA: 0s - loss: 0.0293 - accuracy:
0.9858
Epoch 145: val_loss improved from 0.22994 to 0.22704, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 229ms/step - loss: 0.0293 -
accuracy: 0.9858 - val_loss: 0.2270 - val_accuracy: 0.9220
Epoch 146/300
18/18 [==============================] - ETA: 0s - loss: 0.0257 - accuracy:
0.9947
Epoch 146: val_loss improved from 0.22704 to 0.22600, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 208ms/step - loss: 0.0257 -
accuracy: 0.9947 - val_loss: 0.2260 - val_accuracy: 0.9220
Epoch 147/300
18/18 [==============================] - ETA: 0s - loss: 0.0197 - accuracy:
0.9947
Epoch 147: val_loss improved from 0.22600 to 0.22490, saving model to
```

```
vgg16_custom.h5
18/18 [==============================] - 4s 207ms/step - loss: 0.0197 -
accuracy: 0.9947 - val_loss: 0.2249 - val_accuracy: 0.9291
Epoch 148/300
18/18 [==============================] - ETA: 0s - loss: 0.0168 - accuracy:
0.9965
Epoch 148: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 162ms/step - loss: 0.0168 -
accuracy: 0.9965 - val_loss: 0.2250 - val_accuracy: 0.9291
Epoch 149/300
18/18 [==============================] - ETA: 0s - loss: 0.0161 - accuracy:
0.9965
Epoch 149: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 154ms/step - loss: 0.0161 -
accuracy: 0.9965 - val_loss: 0.2255 - val_accuracy: 0.9220
Epoch 150/300
18/18 [==============================] - ETA: 0s - loss: 0.0419 - accuracy:
0.9858
Epoch 150: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 143ms/step - loss: 0.0419 -
accuracy: 0.9858 - val_loss: 0.2271 - val_accuracy: 0.9220
Epoch 151/300
18/18 [==============================] - ETA: 0s - loss: 0.0234 - accuracy:
0.9929
Epoch 151: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 151ms/step - loss: 0.0234 -
accuracy: 0.9929 - val_loss: 0.2315 - val_accuracy: 0.9291
Epoch 152/300
18/18 [==============================] - ETA: 0s - loss: 0.0125 - accuracy:
0.9965
Epoch 152: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 150ms/step - loss: 0.0125 -
accuracy: 0.9965 - val_loss: 0.2337 - val_accuracy: 0.9362
Epoch 153/300
18/18 [==============================] - ETA: 0s - loss: 0.0120 - accuracy:
0.9982
Epoch 153: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 184ms/step - loss: 0.0120 -
accuracy: 0.9982 - val_loss: 0.2349 - val_accuracy: 0.9362
Epoch 154/300
18/18 [==============================] - ETA: 0s - loss: 0.0104 - accuracy:
1.0000
Epoch 154: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 156ms/step - loss: 0.0104 -
accuracy: 1.0000 - val_loss: 0.2350 - val_accuracy: 0.9362
Epoch 155/300
18/18 [==============================] - ETA: 0s - loss: 0.0272 - accuracy:
0.9929
```

```
Epoch 155: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 144ms/step - loss: 0.0272 -
accuracy: 0.9929 - val_loss: 0.2341 - val_accuracy: 0.9362
Epoch 156/300
18/18 [==============================] - ETA: 0s - loss: 0.0116 - accuracy:
1.0000
Epoch 156: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 150ms/step - loss: 0.0116 -
accuracy: 1.0000 - val_loss: 0.2318 - val_accuracy: 0.9362
Epoch 157/300
18/18 [==============================] - ETA: 0s - loss: 0.0228 - accuracy:
0.9894
Epoch 157: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 151ms/step - loss: 0.0228 -
accuracy: 0.9894 - val_loss: 0.2297 - val_accuracy: 0.9291
Epoch 158/300
18/18 [==============================] - ETA: 0s - loss: 0.0206 - accuracy:
0.9894
Epoch 158: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 155ms/step - loss: 0.0206 -
accuracy: 0.9894 - val_loss: 0.2308 - val_accuracy: 0.9291
Epoch 159/300
18/18 [==============================] - ETA: 0s - loss: 0.0200 - accuracy:
0.9929
Epoch 159: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 151ms/step - loss: 0.0200 -
accuracy: 0.9929 - val_loss: 0.2333 - val_accuracy: 0.9291
Epoch 160/300
18/18 [==============================] - ETA: 0s - loss: 0.0233 - accuracy:
0.9929
Epoch 160: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 145ms/step - loss: 0.0233 -
accuracy: 0.9929 - val_loss: 0.2314 - val_accuracy: 0.9291
Epoch 161/300
18/18 [==============================] - ETA: 0s - loss: 0.0089 - accuracy:
0.9965
Epoch 161: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 145ms/step - loss: 0.0089 -
accuracy: 0.9965 - val_loss: 0.2304 - val_accuracy: 0.9291
Epoch 162/300
18/18 [==============================] - ETA: 0s - loss: 0.0092 - accuracy:
0.9982
Epoch 162: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 167ms/step - loss: 0.0092 -
accuracy: 0.9982 - val_loss: 0.2300 - val_accuracy: 0.9291
Epoch 163/300
18/18 [==============================] - ETA: 0s - loss: 0.0148 - accuracy:
0.9947
```

```
Epoch 163: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 147ms/step - loss: 0.0148 -
accuracy: 0.9947 - val_loss: 0.2311 - val_accuracy: 0.9291
Epoch 164/300
18/18 [==============================] - ETA: 0s - loss: 0.0105 - accuracy:
0.9965
Epoch 164: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 151ms/step - loss: 0.0105 -
accuracy: 0.9965 - val_loss: 0.2307 - val_accuracy: 0.9291
Epoch 165/300
18/18 [==============================] - ETA: 0s - loss: 0.0206 - accuracy:
0.9894
Epoch 165: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 143ms/step - loss: 0.0206 -
accuracy: 0.9894 - val_loss: 0.2317 - val_accuracy: 0.9362
Epoch 166/300
18/18 [==============================] - ETA: 0s - loss: 0.0185 - accuracy:
0.9894
Epoch 166: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 150ms/step - loss: 0.0185 -
accuracy: 0.9894 - val_loss: 0.2318 - val_accuracy: 0.9362
Epoch 167/300
18/18 [==============================] - ETA: 0s - loss: 0.0123 - accuracy:
0.9965
Epoch 167: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 149ms/step - loss: 0.0123 -
accuracy: 0.9965 - val_loss: 0.2296 - val_accuracy: 0.9362
Epoch 168/300
18/18 [==============================] - ETA: 0s - loss: 0.0156 - accuracy:
0.9947
Epoch 168: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 151ms/step - loss: 0.0156 -
accuracy: 0.9947 - val_loss: 0.2312 - val_accuracy: 0.9362
Epoch 169/300
18/18 [==============================] - ETA: 0s - loss: 0.0167 - accuracy:
0.9947
Epoch 169: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 145ms/step - loss: 0.0167 -
accuracy: 0.9947 - val_loss: 0.2292 - val_accuracy: 0.9362
Epoch 170/300
18/18 [==============================] - ETA: 0s - loss: 0.0141 - accuracy:
0.9982
Epoch 170: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 142ms/step - loss: 0.0141 -
accuracy: 0.9982 - val_loss: 0.2274 - val_accuracy: 0.9362
Epoch 171/300
18/18 [==============================] - ETA: 0s - loss: 0.0130 - accuracy:
0.9947
```

```
Epoch 171: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 146ms/step - loss: 0.0130 -
accuracy: 0.9947 - val_loss: 0.2266 - val_accuracy: 0.9291
Epoch 172/300
18/18 [==============================] - ETA: 0s - loss: 0.0103 - accuracy:
0.9965
Epoch 172: val_loss did not improve from 0.22490
18/18 [==============================] - 3s 180ms/step - loss: 0.0103 -
accuracy: 0.9965 - val_loss: 0.2258 - val_accuracy: 0.9291
Epoch 173/300
18/18 [==============================] - ETA: 0s - loss: 0.0163 - accuracy:
0.9929
Epoch 173: val_loss improved from 0.22490 to 0.22428, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 205ms/step - loss: 0.0163 -
accuracy: 0.9929 - val_loss: 0.2243 - val_accuracy: 0.9291
Epoch 174/300
18/18 [==============================] - ETA: 0s - loss: 0.0149 - accuracy:
0.9982
Epoch 174: val_loss did not improve from 0.22428
18/18 [==============================] - 3s 144ms/step - loss: 0.0149 -
accuracy: 0.9982 - val_loss: 0.2254 - val_accuracy: 0.9291
Epoch 175/300
18/18 [==============================] - ETA: 0s - loss: 0.0139 - accuracy:
0.9965
Epoch 175: val_loss did not improve from 0.22428
18/18 [==============================] - 3s 147ms/step - loss: 0.0139 -
accuracy: 0.9965 - val_loss: 0.2262 - val_accuracy: 0.9291
Epoch 176/300
18/18 [==============================] - ETA: 0s - loss: 0.0241 - accuracy:
0.9911
Epoch 176: val_loss did not improve from 0.22428
18/18 [==============================] - 3s 161ms/step - loss: 0.0241 -
accuracy: 0.9911 - val_loss: 0.2278 - val_accuracy: 0.9362
Epoch 177/300
18/18 [==============================] - ETA: 0s - loss: 0.0107 - accuracy:
0.9982
Epoch 177: val_loss did not improve from 0.22428
18/18 [==============================] - 3s 149ms/step - loss: 0.0107 -
accuracy: 0.9982 - val_loss: 0.2268 - val_accuracy: 0.9362
Epoch 178/300
18/18 [==============================] - ETA: 0s - loss: 0.0105 - accuracy:
0.9965
Epoch 178: val_loss did not improve from 0.22428
18/18 [==============================] - 3s 146ms/step - loss: 0.0105 -
accuracy: 0.9965 - val_loss: 0.2276 - val_accuracy: 0.9362
Epoch 179/300
18/18 [==============================] - ETA: 0s - loss: 0.0196 - accuracy:
```

```
0.9965
Epoch 179: val_loss did not improve from 0.22428
18/18 [==============================] - 3s 152ms/step - loss: 0.0196 -
accuracy: 0.9965 - val_loss: 0.2250 - val_accuracy: 0.9362
Epoch 180/300
18/18 [==============================] - ETA: 0s - loss: 0.0236 - accuracy:
0.9929
Epoch 180: val_loss improved from 0.22428 to 0.22277, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 201ms/step - loss: 0.0236 -
accuracy: 0.9929 - val_loss: 0.2228 - val_accuracy: 0.9291
Epoch 181/300
18/18 [==============================] - ETA: 0s - loss: 0.0104 - accuracy:
1.0000
Epoch 181: val_loss improved from 0.22277 to 0.22217, saving model to
vgg16_custom.h5
18/18 [==============================] - 4s 210ms/step - loss: 0.0104 -
accuracy: 1.0000 - val_loss: 0.2222 - val_accuracy: 0.9291
Epoch 182/300
18/18 [==============================] - ETA: 0s - loss: 0.0101 - accuracy:
1.0000
Epoch 182: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 173ms/step - loss: 0.0101 -
accuracy: 1.0000 - val_loss: 0.2223 - val_accuracy: 0.9291
Epoch 183/300
18/18 [==============================] - ETA: 0s - loss: 0.0146 - accuracy:
0.9929
Epoch 183: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 155ms/step - loss: 0.0146 -
accuracy: 0.9929 - val_loss: 0.2233 - val_accuracy: 0.9291
Epoch 184/300
18/18 [==============================] - ETA: 0s - loss: 0.0193 - accuracy:
0.9947
Epoch 184: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 149ms/step - loss: 0.0193 -
accuracy: 0.9947 - val_loss: 0.2252 - val_accuracy: 0.9362
Epoch 185/300
18/18 [==============================] - ETA: 0s - loss: 0.0188 - accuracy:
0.9911
Epoch 185: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 154ms/step - loss: 0.0188 -
accuracy: 0.9911 - val_loss: 0.2261 - val_accuracy: 0.9362
Epoch 186/300
18/18 [==============================] - ETA: 0s - loss: 0.0143 - accuracy:
0.9965
Epoch 186: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 149ms/step - loss: 0.0143 -
accuracy: 0.9965 - val_loss: 0.2292 - val_accuracy: 0.9362
```

```
Epoch 187/300
18/18 [==============================] - ETA: 0s - loss: 0.0212 - accuracy:
0.9894
Epoch 187: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 176ms/step - loss: 0.0212 -
accuracy: 0.9894 - val_loss: 0.2308 - val_accuracy: 0.9362
Epoch 188/300
18/18 [==============================] - ETA: 0s - loss: 0.0091 - accuracy:
0.9982
Epoch 188: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 158ms/step - loss: 0.0091 -
accuracy: 0.9982 - val_loss: 0.2314 - val_accuracy: 0.9362
Epoch 189/300
18/18 [==============================] - ETA: 0s - loss: 0.0090 - accuracy:
1.0000
Epoch 189: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 144ms/step - loss: 0.0090 -
accuracy: 1.0000 - val_loss: 0.2299 - val_accuracy: 0.9362
Epoch 190/300
18/18 [==============================] - ETA: 0s - loss: 0.0100 - accuracy:
0.9982
Epoch 190: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 149ms/step - loss: 0.0100 -
accuracy: 0.9982 - val_loss: 0.2303 - val_accuracy: 0.9362
Epoch 191/300
18/18 [==============================] - ETA: 0s - loss: 0.0086 - accuracy:
1.0000
Epoch 191: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 149ms/step - loss: 0.0086 -
accuracy: 1.0000 - val_loss: 0.2298 - val_accuracy: 0.9362
Epoch 192/300
18/18 [==============================] - ETA: 0s - loss: 0.0151 - accuracy:
0.9947
Epoch 192: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 144ms/step - loss: 0.0151 -
accuracy: 0.9947 - val_loss: 0.2315 - val_accuracy: 0.9362
Epoch 193/300
18/18 [==============================] - ETA: 0s - loss: 0.0192 - accuracy:
0.9982
Epoch 193: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 148ms/step - loss: 0.0192 -
accuracy: 0.9982 - val_loss: 0.2336 - val_accuracy: 0.9362
Epoch 194/300
18/18 [==============================] - ETA: 0s - loss: 0.0108 - accuracy:
0.9982
Epoch 194: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 159ms/step - loss: 0.0108 -
accuracy: 0.9982 - val_loss: 0.2349 - val_accuracy: 0.9362
```

```
Epoch 195/300
18/18 [==============================] - ETA: 0s - loss: 0.0153 - accuracy:
0.9947
Epoch 195: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 151ms/step - loss: 0.0153 -
accuracy: 0.9947 - val_loss: 0.2364 - val_accuracy: 0.9362
Epoch 196/300
18/18 [==============================] - ETA: 0s - loss: 0.0171 - accuracy:
0.9947
Epoch 196: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 150ms/step - loss: 0.0171 -
accuracy: 0.9947 - val_loss: 0.2343 - val_accuracy: 0.9362
Epoch 197/300
18/18 [==============================] - ETA: 0s - loss: 0.0117 - accuracy:
0.9982
Epoch 197: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 163ms/step - loss: 0.0117 -
accuracy: 0.9982 - val_loss: 0.2298 - val_accuracy: 0.9362
Epoch 198/300
18/18 [==============================] - ETA: 0s - loss: 0.0119 - accuracy:
0.9965
Epoch 198: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 143ms/step - loss: 0.0119 -
accuracy: 0.9965 - val_loss: 0.2279 - val_accuracy: 0.9362
Epoch 199/300
18/18 [==============================] - ETA: 0s - loss: 0.0076 - accuracy:
1.0000
Epoch 199: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 161ms/step - loss: 0.0076 -
accuracy: 1.0000 - val_loss: 0.2270 - val_accuracy: 0.9362
Epoch 200/300
18/18 [==============================] - ETA: 0s - loss: 0.0081 - accuracy:
0.9982
Epoch 200: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 153ms/step - loss: 0.0081 -
accuracy: 0.9982 - val_loss: 0.2284 - val_accuracy: 0.9362
Epoch 201/300
18/18 [==============================] - ETA: 0s - loss: 0.0105 - accuracy:
0.9982
Epoch 201: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 146ms/step - loss: 0.0105 -
accuracy: 0.9982 - val_loss: 0.2291 - val_accuracy: 0.9362
Epoch 202/300
18/18 [==============================] - ETA: 0s - loss: 0.0113 - accuracy:
0.9965
Epoch 202: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 158ms/step - loss: 0.0113 -
accuracy: 0.9965 - val_loss: 0.2270 - val_accuracy: 0.9362
```

```
Epoch 203/300
18/18 [==============================] - ETA: 0s - loss: 0.0105 - accuracy:
0.9982
Epoch 203: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 153ms/step - loss: 0.0105 -
accuracy: 0.9982 - val_loss: 0.2281 - val_accuracy: 0.9362
Epoch 204/300
18/18 [==============================] - ETA: 0s - loss: 0.0082 - accuracy:
0.9982
Epoch 204: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 152ms/step - loss: 0.0082 -
accuracy: 0.9982 - val_loss: 0.2294 - val_accuracy: 0.9362
Epoch 205/300
18/18 [==============================] - ETA: 0s - loss: 0.0130 - accuracy:
0.9982
Epoch 205: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 150ms/step - loss: 0.0130 -
accuracy: 0.9982 - val_loss: 0.2330 - val_accuracy: 0.9362
Epoch 206/300
18/18 [==============================] - ETA: 0s - loss: 0.0072 - accuracy:
0.9965
Epoch 206: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 145ms/step - loss: 0.0072 -
accuracy: 0.9965 - val_loss: 0.2336 - val_accuracy: 0.9362
Epoch 207/300
18/18 [==============================] - ETA: 0s - loss: 0.0064 - accuracy:
1.0000
Epoch 207: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 143ms/step - loss: 0.0064 -
accuracy: 1.0000 - val_loss: 0.2320 - val_accuracy: 0.9362
Epoch 208/300
18/18 [==============================] - ETA: 0s - loss: 0.0145 - accuracy:
0.9947
Epoch 208: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 183ms/step - loss: 0.0145 -
accuracy: 0.9947 - val_loss: 0.2293 - val_accuracy: 0.9362
Epoch 209/300
18/18 [==============================] - ETA: 0s - loss: 0.0062 - accuracy:
1.0000
Epoch 209: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 141ms/step - loss: 0.0062 -
accuracy: 1.0000 - val_loss: 0.2286 - val_accuracy: 0.9362
Epoch 210/300
18/18 [==============================] - ETA: 0s - loss: 0.0081 - accuracy:
0.9982
Epoch 210: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 144ms/step - loss: 0.0081 -
accuracy: 0.9982 - val_loss: 0.2283 - val_accuracy: 0.9362
```

```
Epoch 211/300
18/18 [==============================] - ETA: 0s - loss: 0.0172 - accuracy:
0.9965
Epoch 211: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 155ms/step - loss: 0.0172 -
accuracy: 0.9965 - val_loss: 0.2306 - val_accuracy: 0.9362
Epoch 212/300
18/18 [==============================] - ETA: 0s - loss: 0.0076 - accuracy:
1.0000
Epoch 212: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 148ms/step - loss: 0.0076 -
accuracy: 1.0000 - val_loss: 0.2302 - val_accuracy: 0.9362
Epoch 213/300
18/18 [==============================] - ETA: 0s - loss: 0.0089 - accuracy:
0.9965
Epoch 213: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 153ms/step - loss: 0.0089 -
accuracy: 0.9965 - val_loss: 0.2279 - val_accuracy: 0.9362
Epoch 214/300
18/18 [==============================] - ETA: 0s - loss: 0.0127 - accuracy:
0.9947
Epoch 214: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 144ms/step - loss: 0.0127 -
accuracy: 0.9947 - val_loss: 0.2261 - val_accuracy: 0.9433
Epoch 215/300
18/18 [==============================] - ETA: 0s - loss: 0.0112 - accuracy:
0.9982
Epoch 215: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 155ms/step - loss: 0.0112 -
accuracy: 0.9982 - val_loss: 0.2232 - val_accuracy: 0.9362
Epoch 216/300
18/18 [==============================] - ETA: 0s - loss: 0.0097 - accuracy:
0.9982
Epoch 216: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 153ms/step - loss: 0.0097 -
accuracy: 0.9982 - val_loss: 0.2262 - val_accuracy: 0.9362
Epoch 217/300
18/18 [==============================] - ETA: 0s - loss: 0.0174 - accuracy:
0.9894
Epoch 217: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 147ms/step - loss: 0.0174 -
accuracy: 0.9894 - val_loss: 0.2290 - val_accuracy: 0.9362
Epoch 218/300
18/18 [==============================] - ETA: 0s - loss: 0.0087 - accuracy:
0.9982
Epoch 218: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 156ms/step - loss: 0.0087 -
accuracy: 0.9982 - val_loss: 0.2257 - val_accuracy: 0.9362
```

```
Epoch 219/300
18/18 [==============================] - ETA: 0s - loss: 0.0049 - accuracy:
1.0000
Epoch 219: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 147ms/step - loss: 0.0049 -
accuracy: 1.0000 - val_loss: 0.2247 - val_accuracy: 0.9362
Epoch 220/300
18/18 [==============================] - ETA: 0s - loss: 0.0054 - accuracy:
0.9982
Epoch 220: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 152ms/step - loss: 0.0054 -
accuracy: 0.9982 - val_loss: 0.2250 - val_accuracy: 0.9362
Epoch 221/300
18/18 [==============================] - ETA: 0s - loss: 0.0069 - accuracy:
0.9982
Epoch 221: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 161ms/step - loss: 0.0069 -
accuracy: 0.9982 - val_loss: 0.2247 - val_accuracy: 0.9362
Epoch 222/300
18/18 [==============================] - ETA: 0s - loss: 0.0105 - accuracy:
0.9982
Epoch 222: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 165ms/step - loss: 0.0105 -
accuracy: 0.9982 - val_loss: 0.2247 - val_accuracy: 0.9433
Epoch 223/300
18/18 [==============================] - ETA: 0s - loss: 0.0116 - accuracy:
0.9965
Epoch 223: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 163ms/step - loss: 0.0116 -
accuracy: 0.9965 - val_loss: 0.2280 - val_accuracy: 0.9362
Epoch 224/300
18/18 [==============================] - ETA: 0s - loss: 0.0113 - accuracy:
0.9982
Epoch 224: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 146ms/step - loss: 0.0113 -
accuracy: 0.9982 - val_loss: 0.2297 - val_accuracy: 0.9362
Epoch 225/300
18/18 [==============================] - ETA: 0s - loss: 0.0063 - accuracy:
0.9982
Epoch 225: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 149ms/step - loss: 0.0063 -
accuracy: 0.9982 - val_loss: 0.2318 - val_accuracy: 0.9362
Epoch 226/300
18/18 [==============================] - ETA: 0s - loss: 0.0062 - accuracy:
0.9965
Epoch 226: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 151ms/step - loss: 0.0062 -
accuracy: 0.9965 - val_loss: 0.2307 - val_accuracy: 0.9362
```

```
Epoch 227/300
18/18 [==============================] - ETA: 0s - loss: 0.0103 - accuracy:
0.9965
Epoch 227: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 149ms/step - loss: 0.0103 -
accuracy: 0.9965 - val_loss: 0.2292 - val_accuracy: 0.9362
Epoch 228/300
18/18 [==============================] - ETA: 0s - loss: 0.0093 - accuracy:
0.9965
Epoch 228: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 145ms/step - loss: 0.0093 -
accuracy: 0.9965 - val_loss: 0.2265 - val_accuracy: 0.9362
Epoch 229/300
18/18 [==============================] - ETA: 0s - loss: 0.0098 - accuracy:
0.9982
Epoch 229: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 167ms/step - loss: 0.0098 -
accuracy: 0.9982 - val_loss: 0.2233 - val_accuracy: 0.9362
Epoch 230/300
18/18 [==============================] - ETA: 0s - loss: 0.0086 - accuracy:
0.9982
Epoch 230: val_loss did not improve from 0.22217
18/18 [==============================] - 3s 151ms/step - loss: 0.0086 -
accuracy: 0.9982 - val_loss: 0.2239 - val_accuracy: 0.9433
Epoch 231/300
18/18 [==============================] - ETA: 0s - loss: 0.0042 - accuracy:
1.0000
Epoch 231: val_loss did not improve from 0.22217
Restoring model weights from the end of the best epoch: 181.
18/18 [==============================] - 3s 160ms/step - loss: 0.0042 -
accuracy: 1.0000 - val_loss: 0.2250 - val_accuracy: 0.9362
Epoch 231: early stopping
```

Examinamos las métricas globales del entrenamiento

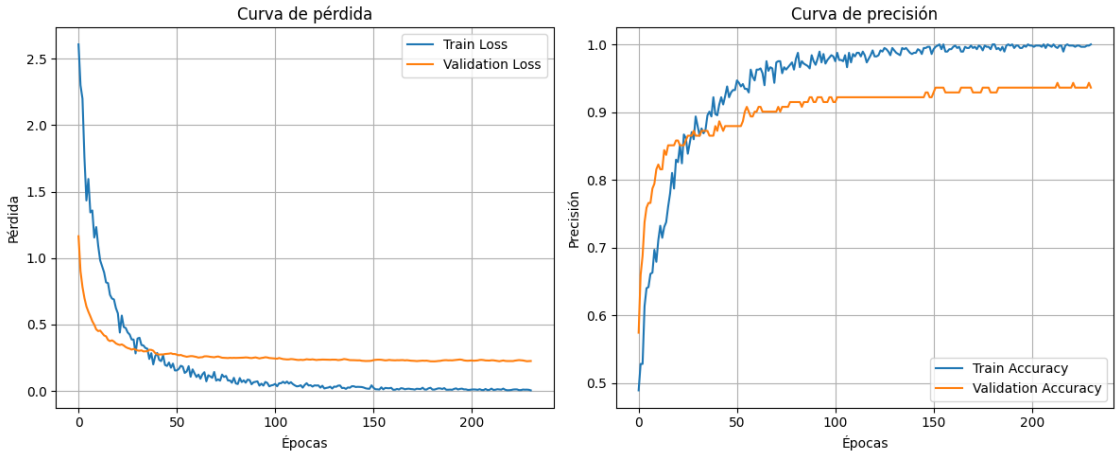
[ ]:
```python
loss2, accuracy2 = model2.evaluate(test_generator, verbose=1)
print(f"Pérdida global: {loss2:.4f}")
print(f"Precisión global (accuracy): {accuracy2:.4f}")
```

```
5/5 [==============================] - 1s 112ms/step - loss: 0.2222 - accuracy:
0.9291
Pérdida global: 0.2222
Precisión global (accuracy): 0.9291
```

La accuracy global de modelo es más alta que en el anterior modelo. La pérdida global también es sensiblemente más baja. Estos datos indican que este modelo predice mejor las clases con los datos

Gráficamos los resultados de este entrenamiento

```
[ ]: # Guardamos el historial
history_dict2 = history1.history

# Curvas de pérdida
plt.figure(figsize=(12, 5))
plt.subplot(1, 2, 1)
plt.plot(history_dict2['loss'], label='Train Loss')
plt.plot(history_dict2['val_loss'], label='Validation Loss')
plt.title('Curva de pérdida')
plt.xlabel('Épocas')
plt.ylabel('Pérdida')
plt.legend()
plt.grid(True)

# Curvas de precisión
plt.subplot(1, 2, 2)
plt.plot(history_dict2['accuracy'], label='Train Accuracy')
plt.plot(history_dict2['val_accuracy'], label='Validation Accuracy')
plt.title('Curva de precisión')
plt.xlabel('Épocas')
plt.ylabel('Precisión')
plt.legend()
plt.grid(True)

plt.tight_layout()
plt.show()
```



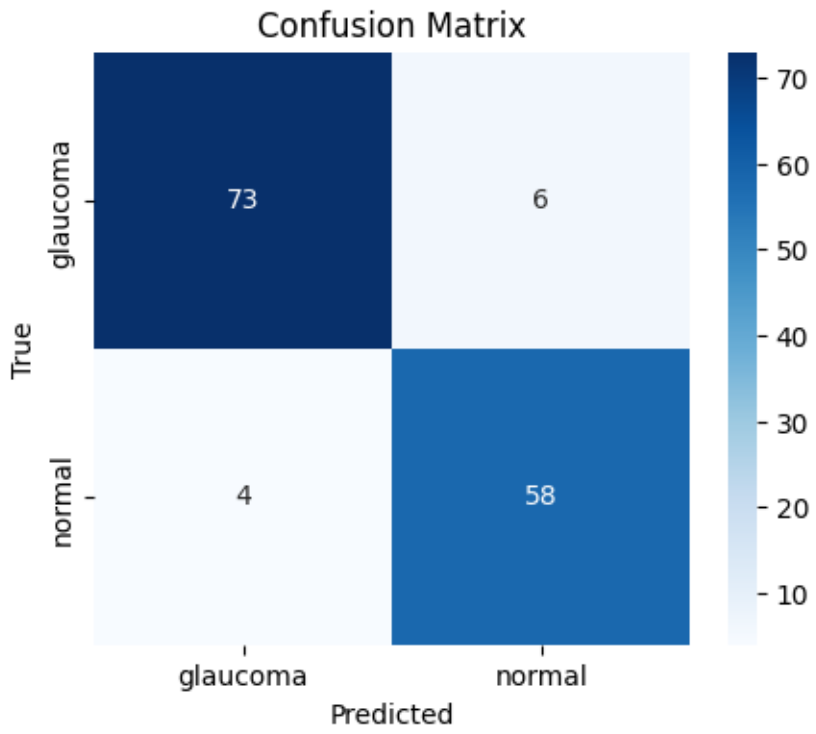
Los resultados son parecidos a simple vista comparado con la otra red. El loss llega a valores muy bajos, casi de 0, rápidamente. Mientras que el acurracy llega a niveles muy altos de la misma forma.

Pero sin nos fijamos con detalle hay pequeñas diferencias que muestran que las redes tienen un funcionamiento diferencial. La red pese a la rapidez con la que muestra buenos valores de accuracy

y loss, al igula que la anterior, no muestra tan rápido sobreajuste, aunque lo acaba mostrando igualmente. El loss en la validación es más bajo que en la anterior, esto puede deberse a que la red tiene más seguridad a la hora de clasificar correctamente las clases,

[ ]:
```
# Obtener predicciones
y_pred_prob = model2.predict(test_generator, verbose=1)
y_pred = (y_pred_prob > 0.5).astype(int).reshape(-1)  # binarizamos

# Etiquetas reales
y_true = test_generator.classes

# Matriz de confusión
conf_mat_ACRIMA = confusion_matrix(y_true, y_pred)

# Informe de clasificación (Precision, Recall, F1)
print("Classification Report:\n")
print(classification_report(y_true, y_pred, target_names=test_generator.
 ↪class_indices.keys()))

# AUC
auc_ACRIMA = roc_auc_score(y_true, y_pred_prob)
print(f" AUC Score: {auc:.4f}")

# Dibujar matriz de confusión
plt.figure(figsize=(5, 4))
sns.heatmap(conf_mat_ACRIMA, annot=True, fmt='d', cmap='Blues',
            xticklabels=test_generator.class_indices.keys(),
            yticklabels=test_generator.class_indices.keys())
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```

```
5/5 [==============================] - 1s 113ms/step
Classification Report:

              precision    recall  f1-score   support

    glaucoma       0.95      0.92      0.94        79
      normal       0.91      0.94      0.92        62

    accuracy                           0.93       141
   macro avg       0.93      0.93      0.93       141
weighted avg       0.93      0.93      0.93       141

 AUC Score: 0.9559
```



En esta matriz de confusión vemos que las métricas son mejores. Todos los indíces pasan el el 90% con seguridad.

2.2 2.2. Determinar el rendimiento de VGG16-g obtenida en 2.1 para el diagnóstico de glaucoma con las retinografías de Rim-One-R2

Descomprimimos el nuevo dataset

[ ]:
```
zip_path = "/notebooks/RIM-ONE_DL_images.zip"
extract_path = "RIM-ONE_DL_dataset"

# Descomprimirr
with zipfile.ZipFile(zip_path, 'r') as zip_ref:
    zip_ref.extractall(extract_path)

# Mostrar los primeros elementos de la carpeta extraída
os.listdir(extract_path)
```

[ ]:
```
['RIM-ONE_DL_images']
```

Al igual que los dataset anteriores utilizamos las pariticiones que ya tiene hechas el archivo original

[ ]:
```
# Rutas a los conjuntos de entrenamiento y test
```

```
train_dir_RIM = "/notebooks/RIM-ONE_DL_dataset/RIM-ONE_DL_images/
 ↪partitioned_by_hospital/training_set"
test_dir_RIM = "/notebooks/RIM-ONE_DL_dataset/RIM-ONE_DL_images/
 ↪partitioned_by_hospital/test_set"

# Generadores con preprocesamiento de VGG16
datagen_RIM = ImageDataGenerator(preprocessing_function=preprocess_input)

# Crear generadores
train_generator_rim = datagen_RIM.flow_from_directory(
    train_dir_RIM,
    target_size=(224, 224),
    batch_size=32,
    class_mode='binary'
)

test_generator_rim = datagen_RIM.flow_from_directory(
    test_dir_RIM,
    target_size=(224, 224),
    batch_size=32,
    class_mode='binary',
    shuffle=False
)
```

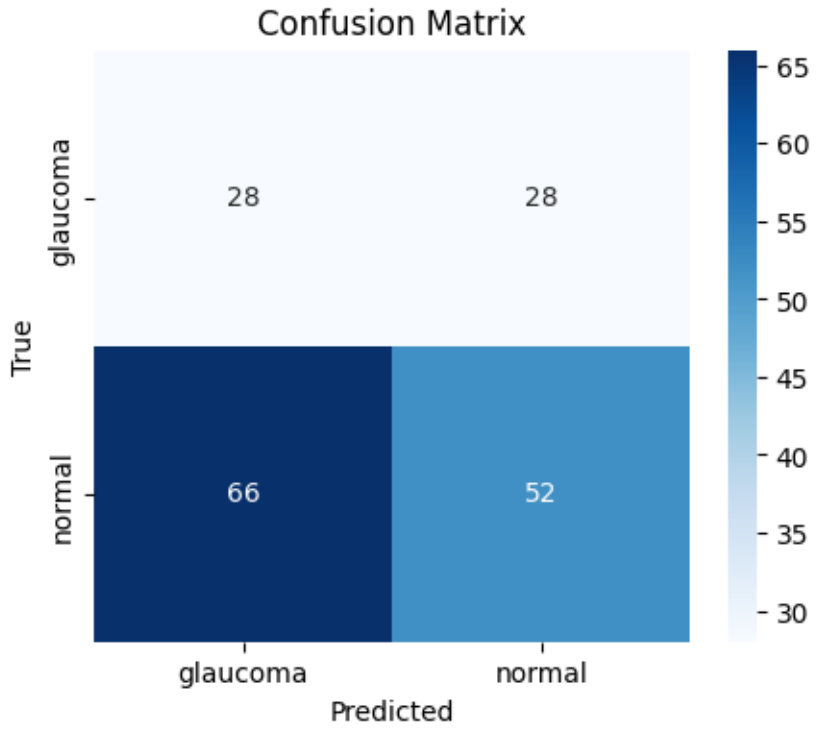
```
Found 311 images belonging to 2 classes.
Found 174 images belonging to 2 classes.
```

Evaluamos la capacidad de clasificar de nuestro modelo2 con la red vgg16_glaucoma

[ ]:
```
y_rim_pred_prob = model2.predict(test_generator_rim)
y_rim_pred = (y_rim_pred_prob > 0.5).astype(int).reshape(-1)
y_rim_true = test_generator_rim.classes

conf_mat_rim = confusion_matrix(y_rim_true, y_rim_pred)

print("Classification Report:\n")
print(classification_report(y_rim_true, y_rim_pred, target_names=test_generator.
 ↪class_indices.keys()))

# AUC
auc_RIM = roc_auc_score(y_rim_true, y_rim_pred_prob)
print(f" AUC Score: {auc:.4f}")

# Dibujar matriz de confusión
plt.figure(figsize=(5, 4))
sns.heatmap(conf_mat_rim, annot=True, fmt='d', cmap='Blues',
            xticklabels=test_generator.class_indices.keys(),
            yticklabels=test_generator.class_indices.keys())
```

```
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```

```
6/6 [==============================] - 1s 228ms/step
Classification Report:

              precision    recall  f1-score   support

    glaucoma       0.30      0.50      0.37        56
      normal       0.65      0.44      0.53       118

    accuracy                           0.46       174
   macro avg       0.47      0.47      0.45       174
weighted avg       0.54      0.46      0.48       174

 AUC Score: 0.9559
```



Las métricas para la base de datos RIM-ONE son muy bajas, más teniendo en cuenta que son una clasificación binaria.

Los resultados obtenidos al evaluar el modelo VGG16-glaucoma (entrenado exclusivamente con ACRIMA) sobre la base de datos RIM-ONE-R2 han mostrado un rendimiento significativamente

más bajo de lo esperado. Este fenómeno revela una clara falta de generalización del modelo hacia un nuevo conjunto de datos del mismo ámbito.

Una causa probable de esta caída de rendimiento es el fenómeno conocido como "cambio de dominio", que se produce cuando las distribuciones estadísticas de los datos de entrenamiento y prueba difieren. Pese a ser los datos del mismo ámbito como es nuestro caso. Los factores que pueden provocar este fénomeno los podemos agrupar en dos grupos: diferencias en los datos, pueden llegar a ser muy sutiles, y diferencias en el entrenamiento de la red.

Las diferencias en los datos pueden ser muy pequeñas. Tan solo diminutas diferencias en el tamaño o la iluminación de la imagen son suficiente para generar este problema. En cambio, cuando nos fijamos en el entrenamiento de la red, la red puede utilizar pequeños detalles para discriminar que no son los que nosotros realmente queremos que discrimine. La red puede estar memorizando ciertos leves detalles y aparentar un buen funcionamiento cuando no es para nada así.

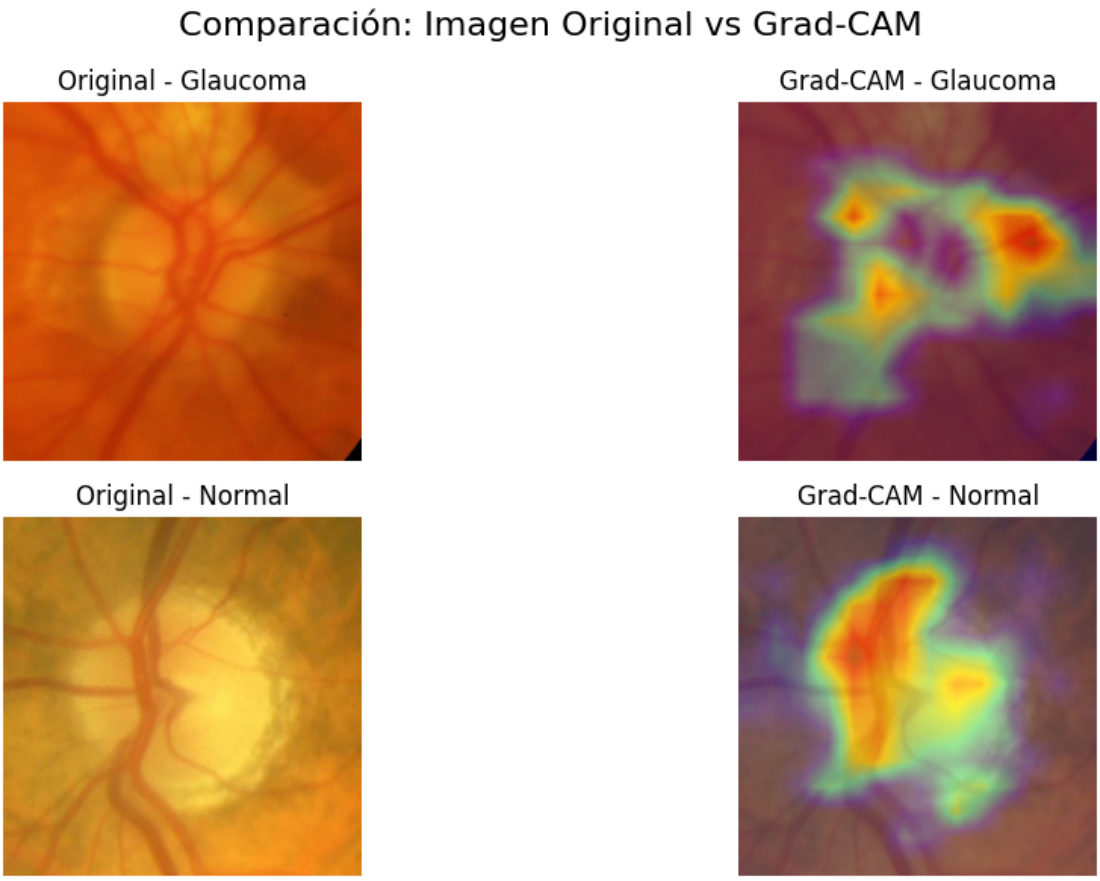
2.3 2.3. Indicar para 2 imágenes elegidas al azar cuáles son las zonas de cada imagen más determinantes del diagnóstico emitido por la red.

Para la base de datos ACRIMA.

[ ]:
```
# Función Grad-CAM
def get_gradcam_heatmap(img_array, model, last_conv_layer_name='block5_conv3'):
    grad_model = tf.keras.models.Model(
        [model.inputs],
        [model.get_layer(last_conv_layer_name).output, model.output]
    )

    with tf.GradientTape() as tape:
        conv_outputs, predictions = grad_model(img_array)
        loss = predictions[:, 0]

    grads = tape.gradient(loss, conv_outputs)
    pooled_grads = tf.reduce_mean(grads, axis=(0, 1, 2))
    conv_outputs = conv_outputs[0]
    heatmap = conv_outputs @ pooled_grads[..., tf.newaxis]
    heatmap = tf.squeeze(heatmap)
    heatmap = tf.maximum(heatmap, 0) / tf.math.reduce_max(heatmap)
    return heatmap.numpy()

# Función que devuelve imagen original y superposición Grad-CAM
def get_original_and_gradcam(image_path, model,␣
 ↪last_conv_layer_name='block5_conv3'):
    # Leer imagen original
    img_orig = cv2.imread(image_path)
    img_orig_resized = cv2.resize(img_orig, (224, 224))

    # Preprocesar imagen para el modelo
```

```
    img_array = preprocess_input(np.
 ↪expand_dims(img_to_array(load_img(image_path, target_size=(224, 224))),␣
 ↪axis=0))

    # Obtener heatmap
    heatmap = get_gradcam_heatmap(img_array, model, last_conv_layer_name)
    heatmap_resized = cv2.resize(heatmap, (224, 224))
    heatmap_color = cv2.applyColorMap(np.uint8(255 * heatmap_resized), cv2.
 ↪COLORMAP_JET)

    # Superponer heatmap
    superimposed = cv2.addWeighted(img_orig_resized, 0.6, heatmap_color, 0.4, 0)

    return cv2.cvtColor(img_orig_resized, cv2.COLOR_BGR2RGB), cv2.
 ↪cvtColor(superimposed, cv2.COLOR_BGR2RGB)

# Rutas de imágenes (ajusta si usas otras)
img_path_glaucoma = "/notebooks/acrima_dataset/ACRIMA/PARTITIONED/Testing/
 ↪glaucoma/Im627_g_ACRIMA.jpg"
img_path_normal = "/notebooks/acrima_dataset/ACRIMA/PARTITIONED/Testing/normal/
 ↪Im241_ACRIMA.jpg"

# Obtener imágenes y grad-cam
orig_glauc, grad_glauc = get_original_and_gradcam(img_path_glaucoma, model2)
orig_norm, grad_norm = get_original_and_gradcam(img_path_normal, model2)

# Mostrar comparación
plt.figure(figsize=(12, 6))

plt.subplot(2, 2, 1)
plt.imshow(orig_glauc)
plt.title("Original - Glaucoma")
plt.axis('off')

plt.subplot(2, 2, 2)
plt.imshow(grad_glauc)
plt.title("Grad-CAM - Glaucoma")
plt.axis('off')

plt.subplot(2, 2, 3)
plt.imshow(orig_norm)
plt.title("Original - Normal")
plt.axis('off')

plt.subplot(2, 2, 4)
plt.imshow(grad_norm)
plt.title("Grad-CAM - Normal")
```

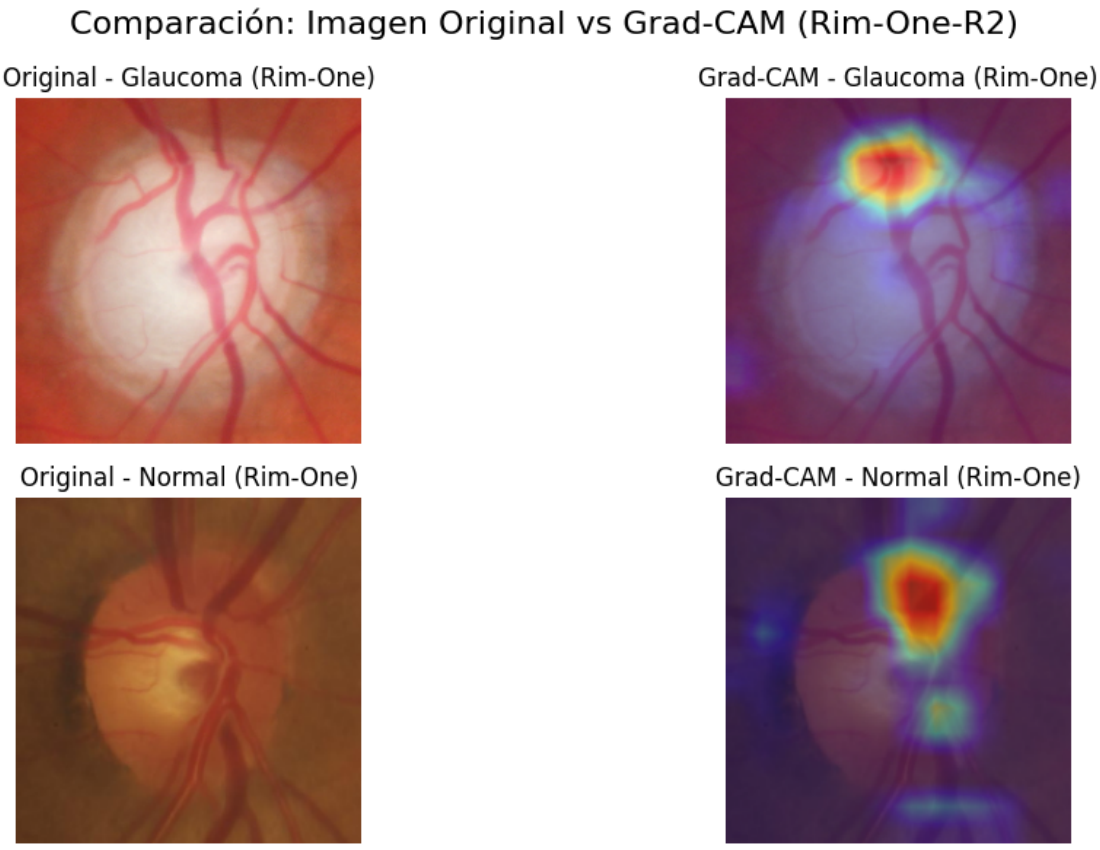
```
plt.axis('off')

plt.suptitle("Comparación: Imagen Original vs Grad-CAM", fontsize=16)
plt.tight_layout()
plt.show()
```



Para la base de datos RIM-ONE.

[ ]:
```
# Nuevas rutas desde la base Rim-One-R2
img_path_glaucoma_rim = "/notebooks/RIM-ONE_DL_dataset/RIM-ONE_DL_images/
 ↪partitioned_by_hospital/test_set/glaucoma/r1_Im069.png"
img_path_normal_rim = "/notebooks/RIM-ONE_DL_dataset/RIM-ONE_DL_images/
 ↪partitioned_by_hospital/test_set/normal/r1_Im001.png"

# Obtener imágenes y grad-cam
orig_glauc_rim, grad_glauc_rim =␣
 ↪get_original_and_gradcam(img_path_glaucoma_rim, model2)
orig_norm_rim, grad_norm_rim = get_original_and_gradcam(img_path_normal_rim,␣
 ↪model2)
```

```
# Mostrar comparación
plt.figure(figsize=(12, 6))

plt.subplot(2, 2, 1)
plt.imshow(orig_glauc_rim)
plt.title("Original - Glaucoma (Rim-One)")
plt.axis('off')

plt.subplot(2, 2, 2)
plt.imshow(grad_glauc_rim)
plt.title("Grad-CAM - Glaucoma (Rim-One)")
plt.axis('off')

plt.subplot(2, 2, 3)
plt.imshow(orig_norm_rim)
plt.title("Original - Normal (Rim-One)")
plt.axis('off')

plt.subplot(2, 2, 4)
plt.imshow(grad_norm_rim)
plt.title("Grad-CAM - Normal (Rim-One)")
plt.axis('off')

plt.suptitle("Comparación: Imagen Original vs Grad-CAM (Rim-One-R2)",␣
 ↪fontsize=16)
plt.tight_layout()
plt.show()
```



Comparando el mapa de calor para las dos bases. Vemos que mientras en la base ACRIMA el modelo se centra en diferentes partes de la imagen. Para RIM-ONE solo se centra únicamente en pequeños detalles de la imagen. Esto apoya la idea de que el modelo no generaliza bien, ya que la red se fija en cosas diferentes dependiendo de la base de datos. Por otro lado, no tengo ningún tipo de conocimiento acerca del glaucoma pero ver en que partes se fija el modelo, puede ser interesante para saber por que la red no consigue generalizar de manera correcta.

3 3. Estudio comparativo de rendimiento

3.1 3.1. Comparar el rendimiento de VGG16-glaucoma en el diagnóstico de glaucoma en ACRIMA y en RimOne-R2, utilizando el área bajo la curva ROC como indicador del rendimiento;

[ ]:
```
print(f"AUC en ACRIMA:     {auc_ACRIMA:.4f}")
print(f"AUC en Rim-One-R2: {auc_RIM:.4f}")
```

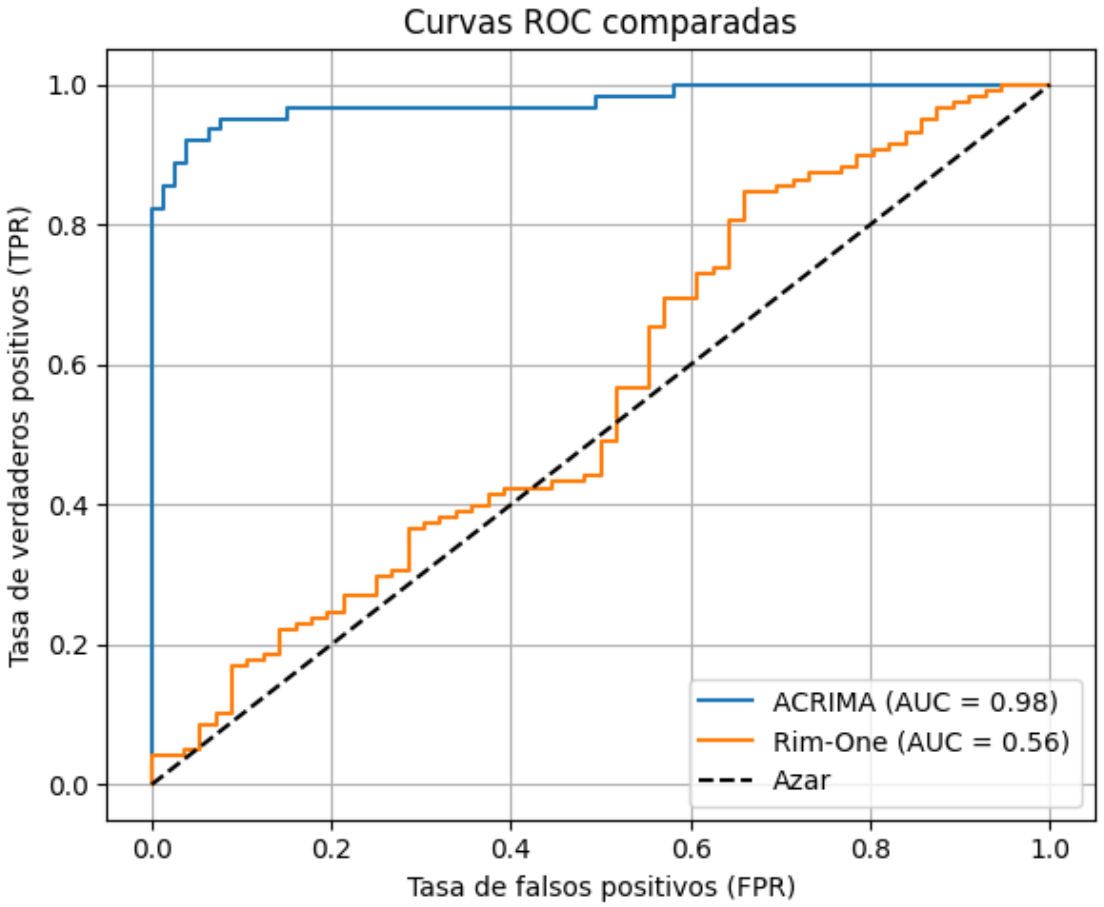
```
AUC en ACRIMA:     0.9755
AUC en Rim-One-R2: 0.5595
```

Estos valores nos muestra que la red para ACRIMA tiene un muy buen valor, 0,97, nos indica que la red discrimina muy bien entre las dos categorías. En cambio, para RIM-ONE el valor es del 0,55,

esto nos indica que el modelo prácticamente discrimina al azar entre las dos categorías.

Representamos la curva ROC para ambas bases de datos

```
[ ]: # Curvas ROC
fpr_acr, tpr_acr, _ = roc_curve(y_true, y_pred_prob)
fpr_rim, tpr_rim, _ = roc_curve(y_rim_true, y_rim_pred_prob)

plt.figure(figsize=(6, 5))
plt.plot(fpr_acr, tpr_acr, label=f"ACRIMA (AUC = {auc_ACRIMA:.2f})")
plt.plot(fpr_rim, tpr_rim, label=f"Rim-One (AUC = {auc_RIM:.2f})")
plt.plot([0, 1], [0, 1], 'k--', label="Azar")
plt.xlabel("Tasa de falsos positivos (FPR)")
plt.ylabel("Tasa de verdaderos positivos (TPR)")
plt.title("Curvas ROC comparadas")
plt.legend()
plt.grid(True)
plt.tight_layout()
plt.show()
```



Estos gráficos nos muestra lo resultados de antes de forma visual. La buena capacidad discriminativa de ACRIMA y la baja capacidad de RIM-ONE que no es mucho mejor que elegir por azar

3.2 3.2. Ídem utilizando otro índice de rendimiento a elegir (justificando la elección);

Los índices de rendimiento que vamos a utilizar son el recall, el log loss, el brier loss y f1 score.

El recall o sensibilidad. Podríamos definirlo como la proporción de positivos reales que fueron correctamente clasificados como positivos. Es un índice muy importante en cualquier situación de diágnostico médico, sobretodo si el costo de dar un falso negativo es alto. Su fórmula es:

$\text{Recall} = \frac{TP}{TP+FN}$

El log-loss o entropía cruzada binaria es la diferencia entre las probabilidades predichas y valores reales (0 o 1). Penaliza las predicciones erróneas hechas con mucha seguridad. Me parece un índice interesante para ver las magnitudes de como falla una red. Los valores más bajos indican mejor ajuste. Su fórmula es:

$\text{LogLoss} = -\frac{1}{N}\sum_{i=1}^{N}[y_i \log(p_i) + (1-y_i)\log(1-p_i)]$

Brier Score es una medida que mide el error cuadrático medio entre la probabilidad predicha y la clase real. Penaliza especialmente tanto los errores como los excesos de cofianza. En interesante usarlo en un contexto médico por que nos dice no solo si acierta o no, si no si lo hace además confianza. Se parece a la medida anterior. Los válores más bajos indican mejor ajuste. Su fórmula es:

$\text{Brier} = \frac{1}{N}\sum_{i=1}^{N}(p_i - y_i)^2$

El f1 score es el promedio ármonico entre precisión y recall. Busca un compromiso entre las dos medidas. Bstante útil cuand las clases están desbalancedas. Un valor alto nos da como información que tenemos un modelo robusto de diagnóstico. Su fórmula es:

$\text{F1} = \frac{2 \cdot \text{Precision} \cdot \text{Recall}}{\text{Precision} + \text{Recall}}$

[ ]:
```
# Cálculo de métricas para ACRIMA
auc_acrima       = roc_auc_score(y_true, y_pred_prob)
recall_acrima    = recall_score(y_true, y_pred)
loss_acrima      = log_loss(y_true, y_pred_prob)
brier_acrima     = brier_score_loss(y_true, y_pred_prob)
f1_acrima        = f1_score(y_true, y_pred)

# Cálculo de métricas para Rim-One-R2
auc_rim       = roc_auc_score(y_rim_true, y_rim_pred_prob)
recall_rim    = recall_score(y_rim_true, y_rim_pred)
loss_rim      = log_loss(y_rim_true, y_rim_pred_prob)
brier_rim     = brier_score_loss(y_rim_true, y_rim_pred_prob)
f1_rim        = f1_score(y_rim_true, y_rim_pred)

# Imprimir tabla comparativa
print("{:<25} {:>12} {:>12}".format("Métrica", "ACRIMA", "Rim-One-R2"))
print("-" * 50)
```

```
print("{:<25} {:>12.4f} {:>12.4f}".format("AUC", auc_acrima, auc_rim))
print("{:<25} {:>12.4f} {:>12.4f}".format("Recall", recall_acrima, recall_rim))
print("{:<25} {:>12.4f} {:>12.4f}".format("Log-loss", loss_acrima, loss_rim))
print("{:<25} {:>12.4f} {:>12.4f}".format("Brier Score", brier_acrima,␣
 ↪brier_rim))
print("{:<25} {:>12.4f} {:>12.4f}".format("F1-score", f1_acrima, f1_rim))
```

```
Métrica                          ACRIMA    Rim-One-R2
--------------------------------------------------
AUC                              0.9755        0.5595
Recall                           0.9355        0.4407
Log-loss                         0.2222        1.6290
Brier Score                      0.0501        0.3995
F1-score                         0.9206        0.5253
```

Recall: En ACRIMA detecta más del 93% de los glaucomas reales (bajo riesgo de falsos negativos). En Rim-One apenas detecta el 44%, lo que implica que más de la mitad de los glaucomas no son identificados. Grave en un contexto médico.

Log-loss: En ACRIMA, el modelo predice probabilidades cercanas a las clases verdaderas. En Rim-One-R2 comete errores graves con alta confianza, lo que se refleja en una entropía cruzada muy alta

Brier Score: En ACRIMA, las probabilidades predichas están bien calibradas y son acertadas. En Rim-One-R2, el modelo da probabilidades alejadas del valor real, mostrando alta incertidumbre.

F1-score: En ACRIMA, el modelo logra un gran equilibrio entre precisión y recall. En Rim-One-R2 el equilibrio es muy pobre, mostrando un rendimiento bajo para discriminar.

3.3 3.3. Comentar la concordancia o discrepancia en las conclusiones obtenidas con ambos Índices de rendimiento.

Los resultados para todos los índices que he utilizado nos muestran una realidad bastante clara. Con la base de datos ACRIMA la red muestra unos valores óptimos, mientras que para RIM-ONE los valores son muy deficientes. Todo esto nos lleva al problema de generalización que tiene la red. Sería interesante entrenar a la red con los datos de RIM-ONE y ver su desempeño con los datos de ACRIMA.

Finalmente me gustaría hablar del problema que presenta la red, la generalización. La red a pesar de haber sido entrenada entrenada en el mismo ámbito que RIM-ONE no presenta mismas aptitudes discriminadoras. Algunas de las posibles soluciones que se me ocurren para intentar atajar este problemas son: utilizar un Data augmentation muy agresivo, validación cruzada, descongelar algunas de las últimas capas convulucionales etc.

4 4. Resumen ejecutivo

1. Evaluar la red VGG16 preentrenada con ImageNet. En este apartado el objetivo era evalaur la red VGG16 con los pesos del entrenamiento con imagenet para diognósticar el glaucoma. Para ello utilizamos el la base de datos ACRIMA. El principal problema que encontré es que la salida de esta red, con estos pesos, era para clasificación múltiple, por lo que tuve que

modificar la salidad de la última capa densa de la red. Los resultados fueron en términos de acurracy y de otrás métricas de la matriz confusión fueron bastante buenos. No obstante, no diría que fueran del todo óptimos para un contexto médico.

2. Aplicar transferencia de aprendizaje. En este segunda parte del trabajo creamos un nuevo modelo apartir de la red VGG16. A esta nueva red le añadimos 3 capas densas al final con dropout. Realizamos un nuevo entrenamiento. El entrenamiento mostro buenos valores, aunque cierto sobre aprendizaje. Este se paró antes del tiempo prefijado con un early stop, sobre el loss del conjunto de validación, parandose si no habia una mejora sustancial durante 50 épocas. Evaluamos la red con una matriz de confusión encontrando resultados óptimos.

   Evaluamos la red con RIM-ONE, una base datos muy similar a ACRIMA, utilizamos una matriz de confusión similar. Los resultados encontrados son muy bajos, de hecho no es muy diferente a elegir por azar. Con estos resultados vemos que la red tiene evidentes problemas para generalizar. Pese a que ambas bases de datos son del mismo ámbito.

   Seguidamente, procedemos mediante Grad-Cam a ver que es en lo que se fija la red para ambas bases datos. Se ve claramente que la red para ACRIMA Se fija en diferentes detalles, mientras que para RIME-ONE se fija en un o dos zonas de la imágen. Todo esto apoya la idea de la baja generalización de la red para ambas bases de datos, ya que deberían fijarse de forma más parecida.

3. Estudio comparativo de rendimiento. Posteriormente evaluamos con el índice AUC, calculo de el área bajo la curva ROC, las diferencias de rendimiento de la red con las dos bases datos. El resultado es bastante claro: Con ACRIMA valores bastante buenos, pero con RIM-ONE muy malos, prácticamente no mejor que el azar.

Finalmente decidimos utilizar otra serie de indices para seguir comparando el rendimiento. Los índices utilizados han sido: AUC, recall, log-loss, brier-score y f1-score. Todos estos índices nos mostraron la misma realidad, la red no ha conseguido generalizar, con ACRIMA tenemos buenos valores discriminativos pero no pasa lo mismo RIM-ONE.

5 5. Progamas utilizados para el trabajo

Las versiones para phyton y de todos los paquetes utilizados

[ ]:
```
import sys
import numpy as np
import os
import requests
import zipfile
import urllib.request
import shutil
import matplotlib
import seaborn
import cv2
import tensorflow as tf
import keras
import sklearn
import PIL
```

```
print(f"Python:            {sys.version.split()[0]}")
print(f"NumPy:             {np.__version__}")
print(f"os:                (sin versión)")
print(f"requests:          {requests.__version__}")
print(f"zipfile:           (sin versión)")
print(f"urllib:            (urllib.request)")
print(f"shutil:            (sin versión)")
print(f"matplotlib:        {matplotlib.__version__}")
print(f"seaborn:           {seaborn.__version__}")
print(f"OpenCV (cv2):      {cv2.__version__}")
print(f"TensorFlow:        {tf.__version__}")
print(f"Keras:             {keras.__version__}")
print(f"Scikit-learn:      {sklearn.__version__}")
print(f"Pillow (PIL):      {PIL.__version__}")
```

```
Python:            3.11.7
NumPy:             1.26.3
os:                (sin versión)
requests:          2.31.0
zipfile:           (sin versión)
urllib:            (urllib.request)
shutil:            (sin versión)
matplotlib:        3.7.3
seaborn:           0.12.2
OpenCV (cv2):      4.8.0
TensorFlow:        2.15.0
Keras:             2.15.0
Scikit-learn:      1.3.0
Pillow (PIL):      9.5.0
```

Para generar el código he utilizado el entorno virtual de Paperspace, en concreto el llamado TensorFlow 2.9.1 5. Para ayudarme con el código he utilizado chatgpt. Por otro lado, he utilizado el entorno virtual de googlecolab para realizar todo el informe. Finalmente para renderizarlo y convertirlo en pdf he usado el programa jupyter notebook.