modelT_featureExtraction

June 12, 2025

[2]:
```
from PIL import Image
from tensorflow import keras
from tensorflow.keras.applications.vgg16 import VGG16
from keras import layers
from keras.preprocessing import image_dataset_from_directory
from keras.utils import to_categorical
import tensorflow as tf
import numpy as np
from keras.preprocessing import image
import matplotlib.pyplot as plt
import seaborn as sns
import pandas as pd
from sklearn.metrics import confusion_matrix
import os, shutil
```

```
2025-06-12 23:08:50.318050: E
external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:467] Unable to register
cuFFT factory: Attempting to register factory for plugin cuFFT when one has
already been registered
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
E0000 00:00:1749766130.449361     565 cuda_dnn.cc:8579] Unable to register cuDNN
factory: Attempting to register factory for plugin cuDNN when one has already
been registered
E0000 00:00:1749766130.483198     565 cuda_blas.cc:1407] Unable to register
cuBLAS factory: Attempting to register factory for plugin cuBLAS when one has
already been registered
W0000 00:00:1749766130.745043     565 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
target more than once.
W0000 00:00:1749766130.745071     565 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
target more than once.
W0000 00:00:1749766130.745074     565 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
target more than once.
W0000 00:00:1749766130.745076     565 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
```

```
target more than once.
2025-06-12 23:08:50.774142: I tensorflow/core/platform/cpu_feature_guard.cc:210]
This TensorFlow binary is optimized to use available CPU instructions in
performance-critical operations.
To enable the following instructions: AVX2 FMA, in other operations, rebuild
TensorFlow with the appropriate compiler flags.
```

1 Funções

[18]:
```python
def get_true_pred(model, dataset):
    y_true = []
    y_pred = []
    for images, labels in dataset.unbatch().batch(1):
        y_true.append(np.argmax(labels.numpy()))
        pred = model.predict(images, verbose=0)
        y_pred.append(np.argmax(pred))
    return np.array(y_true), np.array(y_pred)
```

[ ]:
```python
def get_features_and_labels(dataset):
    all_features = []
    all_labels = []
    for images, labels in dataset:
        preprocessed_images = keras.applications.vgg16.preprocess_input(images)
        features = conv_base.predict(preprocessed_images)
        all_features.append(features)
        all_labels.append(labels)
    return np.concatenate(all_features), np.concatenate(all_labels)
```

1.1 Carregamento do dataset

Carrega o dataset distribuido pelos diferentes conjuntos de dados.

[4]:
```python
train_dir = 'Dataset/archive/seg_train'
validation_dir = 'Dataset/archive/seg_val'
test_dir = 'Dataset/archive/seg_test'

train_buildings_dir = 'Dataset/archive/seg_train/buildings/'
train_forest_dir = 'Dataset/archive/seg_train/forest'
train_glacier_dir = 'Dataset/archive/seg_train/glacier'
train_mountain_dir = 'Dataset/archive/seg_train/mountain'
train_sea_dir = 'Dataset/archive/seg_train/sea'
train_street_dir = 'Dataset/archive/seg_train/street'

val_buildings_dir = 'Dataset/archive/seg_val/buildings'
val_forest_dir = 'Dataset/archive/seg_val/forest'
val_glacier_dir = 'Dataset/archive/seg_val/glacier'
val_mountain_dir = 'Dataset/archive/seg_val/mountain'
```

```
val_sea_dir = 'Dataset/archive/seg_val/sea'
val_street_dir = 'Dataset/archive/seg_val/street'

test_buildings_dir = 'Dataset/archive/seg_test/buildings'
test_forest_dir = 'Dataset/archive/seg_test/forest'
test_glacier_dir = 'Dataset/archive/seg_test/glacier'
test_mountain_dir = 'Dataset/archive/seg_test/mountain'
test_sea_dir = 'Dataset/archive/seg_test/sea'
test_street_dir = 'Dataset/archive/seg_test/street'

print('total training buildings images:', len(os.listdir(train_buildings_dir)))
print('total training forest images:', len(os.listdir(train_forest_dir)))
print('total training glacier images:', len(os.listdir(train_glacier_dir)))
print('total training mountain images:', len(os.listdir(train_mountain_dir)))
print('total training sea images:', len(os.listdir(train_sea_dir)))
print('total training street images:', len(os.listdir(train_street_dir)))

print('total validation buildings images:', len(os.listdir(val_buildings_dir)))
print('total validation forest images:', len(os.listdir(val_forest_dir)))
print('total validation glacier images:', len(os.listdir(val_glacier_dir)))
print('total validation mountain images:', len(os.listdir(val_mountain_dir)))
print('total validation sea images:', len(os.listdir(val_sea_dir)))
print('total validation street images:', len(os.listdir(val_street_dir)))

print('total test buildings images:', len(os.listdir(test_buildings_dir)))
print('total test forest images:', len(os.listdir(test_forest_dir)))
print('total test glacier images:', len(os.listdir(test_glacier_dir)))
print('total test mountain images:', len(os.listdir(test_mountain_dir)))
print('total test sea images:', len(os.listdir(test_sea_dir)))
print('total test street images:', len(os.listdir(test_street_dir)))
```

```
total training buildings images: 1691
total training forest images: 1771
total training glacier images: 1904
total training mountain images: 2012
total training sea images: 1774
total training street images: 1882
total validation buildings images: 500
total validation forest images: 500
total validation glacier images: 500
total validation mountain images: 500
total validation sea images: 500
total validation street images: 500
total test buildings images: 437
total test forest images: 474
total test glacier images: 553
total test mountain images: 525
total test sea images: 510
```

```
total test street images: 501
```

1.2 Distribuição de imagens por classe e por conjunto de dados

As imagens estão distribuidas por 3 conjuntos de dados: train, validation e test. Cada um desses conjuntos está distribuido por 6 classes: buildings, forest, glacier, mountain, sea e street.

1.2.1 Número total de imagens por classe:

Classe	Treino	Validação	Teste	Total
Buildings	1691	500	437	2628
Forest	1771	500	474	2745
Glacier	1904	500	553	2957
Mountain	2012	500	525	3037
Sea	1774	500	510	2784
Street	1882	500	501	2883
Total	**11034**	**3000**	**3000**	**17034**

1.2.2 Número total de imagens por conjunto de dados:

Conjunto de dados	Total
Treino	11034
Validação	3000
Teste	3000
Total geral	**17034**

1.3 Processamento dos dados

Carrega, redimensiona e organiza imagens em batches com rótulos one-hot, preparando os dados de treino, validação e teste.

[6]:
```
IMG_SIZE = 150
BATCH_SIZE = 32

# Processing the data
train_dataset = image_dataset_from_directory(
    train_dir,
    label_mode='categorical',
    image_size=(IMG_SIZE, IMG_SIZE),
    batch_size=BATCH_SIZE)

validation_dataset = image_dataset_from_directory(
    validation_dir,
    label_mode='categorical',
    image_size=(IMG_SIZE, IMG_SIZE),
    batch_size=BATCH_SIZE)
```

```
test_dataset = image_dataset_from_directory(
    test_dir,
    label_mode='categorical',
    image_size=(IMG_SIZE, IMG_SIZE),
    batch_size=BATCH_SIZE)

print(test_dataset)
class_names = train_dataset.class_names
print("Classes:", class_names)
```

```
Found 11034 files belonging to 6 classes.
Found 3000 files belonging to 6 classes.
Found 3000 files belonging to 6 classes.
<_PrefetchDataset element_spec=(TensorSpec(shape=(None, 150, 150, 3),
dtype=tf.float32, name=None), TensorSpec(shape=(None, 6), dtype=tf.float32,
name=None))>
Classes: ['buildings', 'forest', 'glacier', 'mountain', 'sea', 'street']
```

2 Carregamento do modelo VGG16

[7]:
```
conv_base = VGG16(weights='imagenet', include_top=False,␣
 ↪input_shape=(150,150,3))
```

3 Feature extraction without data augmentation

3.1 Extração de Features e Labels dos conjuntos de dados

[9]:
```
train_features, train_labels = get_features_and_labels(train_dataset)
val_features, val_labels = get_features_and_labels(validation_dataset)
test_features, test_labels = get_features_and_labels(test_dataset)
```

```
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
I0000 00:00:1749666649.546561   81960 service.cc:152] XLA service 0x7d7338004590
initialized for platform CUDA (this does not guarantee that XLA will be used).
Devices:
I0000 00:00:1749666649.546628   81960 service.cc:160]   StreamExecutor device
(0): NVIDIA GeForce GTX 1070, Compute Capability 6.1
2025-06-11 19:30:49.556141: I
tensorflow/compiler/mlir/tensorflow/utils/dump_mlir_util.cc:269] disabling MLIR
crash reproducer, set env var `MLIR_CRASH_REPRODUCER_DIRECTORY` to enable.
I0000 00:00:1749666649.641743   81960 cuda_dnn.cc:529] Loaded cuDNN version
90300
2025-06-11 19:30:52.603001: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
```

activation.39 = (f32[32,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,3,150,150]{3,2,1,0} %bitcast.396, f32[64,3,3,3]{3,2,1,0}
%bitcast.403, f32[64]{0} %bitcast.405), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block1_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:30:52.925949: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.40 = (f32[32,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,64,150,150]{3,2,1,0} %bitcast.410, f32[64,64,3,3]{3,2,1,0}
%bitcast.417, f32[64]{0} %bitcast.419), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block1_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:30:53.928475: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.41 = (f32[32,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,64,75,75]{3,2,1,0} %bitcast.426, f32[128,64,3,3]{3,2,1,0}
%bitcast.433, f32[128]{0} %bitcast.435), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block2_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:30:54.592827: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.42 = (f32[32,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,128,75,75]{3,2,1,0} %bitcast.440, f32[128,128,3,3]{3,2,1,0}
%bitcast.447, f32[128]{0} %bitcast.449), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block2_conv2_1/convolution"

source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:30:55.341905: I external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-activation.43 = (f32[32,256,37,37]{3,2,1,0}, u8[0]{0}) custom-call(f32[32,128,37,37]{3,2,1,0} %bitcast.455, f32[256,128,3,3]{3,2,1,0} %bitcast.462, f32[256]{0} %bitcast.464), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type="Conv2D" op_name="vgg16_1/block3_conv1_1/convolution" source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:30:55.772829: I external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-activation.44 = (f32[32,256,37,37]{3,2,1,0}, u8[0]{0}) custom-call(f32[32,256,37,37]{3,2,1,0} %bitcast.469, f32[256,256,3,3]{3,2,1,0} %bitcast.476, f32[256]{0} %bitcast.478), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type="Conv2D" op_name="vgg16_1/block3_conv2_1/convolution" source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:30:56.565733: I external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-activation.46 = (f32[32,512,18,18]{3,2,1,0}, u8[0]{0}) custom-call(f32[32,256,18,18]{3,2,1,0} %bitcast.498, f32[512,256,3,3]{3,2,1,0} %bitcast.505, f32[512]{0} %bitcast.507), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type="Conv2D" op_name="vgg16_1/block4_conv1_1/convolution" source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:30:56.980331: I

```
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.47 = (f32[32,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,512,18,18]{3,2,1,0} %bitcast.512, f32[512,512,3,3]{3,2,1,0}
%bitcast.519, f32[512]{0} %bitcast.521), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block4_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:30:57.762190: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.49 = (f32[32,512,9,9]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,512,9,9]{3,2,1,0} %bitcast.541, f32[512,512,3,3]{3,2,1,0}
%bitcast.548, f32[512]{0} %bitcast.550), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block5_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}

1/1            9s 9s/step

I0000 00:00:1749666658.422950   81960 device_compiler.h:188] Compiled cluster
using XLA!  This line is logged at most once for the lifetime of the process.

1/1            0s 113ms/step
1/1            0s 102ms/step
1/1            0s 110ms/step
1/1            0s 106ms/step
1/1            0s 105ms/step
1/1            0s 101ms/step
1/1            0s 101ms/step
1/1            0s 96ms/step
1/1            0s 95ms/step
1/1            0s 105ms/step
1/1            0s 116ms/step
1/1            0s 103ms/step
1/1            0s 94ms/step
1/1            0s 98ms/step
1/1            0s 95ms/step
1/1            0s 115ms/step
```

```
1/1             0s 92ms/step
1/1             0s 110ms/step
1/1             0s 93ms/step
1/1             0s 99ms/step
1/1             0s 93ms/step
1/1             0s 94ms/step
1/1             0s 90ms/step
1/1             0s 91ms/step
1/1             0s 92ms/step
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1/1             0s 102ms/step
1/1             0s 94ms/step
1/1             0s 105ms/step
1/1             0s 98ms/step
1/1             0s 90ms/step
1/1             0s 87ms/step
1/1             0s 90ms/step
1/1             0s 92ms/step
1/1             0s 88ms/step
1/1             0s 94ms/step
1/1             0s 91ms/step
1/1             0s 93ms/step
1/1             0s 93ms/step
1/1             0s 92ms/step
```

```
1/1             0s 93ms/step
1/1             0s 94ms/step
1/1             0s 93ms/step
1/1             0s 92ms/step
1/1             0s 95ms/step
1/1             0s 96ms/step
1/1             0s 96ms/step
1/1             0s 96ms/step
1/1             0s 97ms/step
1/1             0s 102ms/step
1/1             0s 95ms/step
1/1             0s 91ms/step
1/1             0s 94ms/step
1/1             0s 92ms/step
1/1             0s 93ms/step
1/1             0s 93ms/step
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1/1             0s 90ms/step
1/1             0s 100ms/step
1/1             0s 91ms/step
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1/1             0s 92ms/step
1/1             0s 92ms/step
1/1             0s 94ms/step
1/1             0s 91ms/step
1/1             0s 97ms/step
1/1             0s 91ms/step
1/1             0s 96ms/step
1/1             0s 100ms/step
1/1             0s 103ms/step
1/1             0s 105ms/step
1/1             0s 95ms/step
1/1             0s 95ms/step
1/1             0s 95ms/step
```

```
1/1             0s 101ms/step
1/1             0s 93ms/step
1/1             0s 90ms/step
1/1             0s 91ms/step
1/1             0s 95ms/step
1/1             0s 102ms/step
1/1             0s 97ms/step
1/1             0s 97ms/step
1/1             0s 91ms/step
1/1             0s 92ms/step
1/1             0s 91ms/step
1/1             0s 97ms/step
1/1             0s 99ms/step
1/1             0s 93ms/step
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1/1             0s 89ms/step
1/1             0s 90ms/step
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1/1             0s 92ms/step
1/1             0s 93ms/step
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1/1             0s 95ms/step
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1/1             0s 97ms/step
1/1             0s 94ms/step
1/1             0s 92ms/step
1/1             0s 90ms/step
1/1             0s 92ms/step
1/1             0s 100ms/step
1/1             0s 95ms/step
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1/1             0s 91ms/step
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1/1             0s 96ms/step
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1/1             0s 96ms/step
1/1             0s 103ms/step
1/1             0s 94ms/step
1/1             0s 90ms/step
1/1             0s 91ms/step
1/1             0s 93ms/step
1/1             0s 98ms/step
1/1             0s 94ms/step
1/1             0s 101ms/step
1/1             0s 96ms/step
1/1             0s 96ms/step
1/1             0s 93ms/step
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1/1             0s 96ms/step
1/1             3s 3s/step
1/1             0s 89ms/step
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1/1             0s 92ms/step
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1/1             0s 97ms/step
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1/1             0s 99ms/step
1/1             0s 98ms/step
1/1             0s 94ms/step
1/1             0s 92ms/step
1/1             0s 95ms/step
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1/1             0s 96ms/step
1/1             0s 96ms/step
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1/1             0s 94ms/step
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1/1             0s 97ms/step
1/1             0s 94ms/step
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1/1             0s 97ms/step
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1/1             0s 92ms/step
1/1             0s 98ms/step
1/1             0s 93ms/step
1/1             0s 89ms/step
1/1             0s 89ms/step
1/1             0s 92ms/step
```

```
2025-06-11 19:31:58.268656: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.39 = (f32[26,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,3,150,150]{3,2,1,0} %bitcast.396, f32[64,3,3,3]{3,2,1,0}
%bitcast.403, f32[64]{0} %bitcast.405), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
```

metadata={op_type="Conv2D" op_name="vgg16_1/block1_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:31:58.480735: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.40 = (f32[26,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,64,150,150]{3,2,1,0} %bitcast.410, f32[64,64,3,3]{3,2,1,0}
%bitcast.417, f32[64]{0} %bitcast.419), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block1_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:31:59.299837: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.41 = (f32[26,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,64,75,75]{3,2,1,0} %bitcast.426, f32[128,64,3,3]{3,2,1,0}
%bitcast.433, f32[128]{0} %bitcast.435), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block2_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:31:59.798240: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.42 = (f32[26,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,128,75,75]{3,2,1,0} %bitcast.440, f32[128,128,3,3]{3,2,1,0}
%bitcast.447, f32[128]{0} %bitcast.449), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block2_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}

```
2025-06-11 19:32:00.408490: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.43 = (f32[26,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,128,37,37]{3,2,1,0} %bitcast.455, f32[256,128,3,3]{3,2,1,0}
%bitcast.462, f32[256]{0} %bitcast.464), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block3_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:00.819178: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.44 = (f32[26,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,256,37,37]{3,2,1,0} %bitcast.469, f32[256,256,3,3]{3,2,1,0}
%bitcast.476, f32[256]{0} %bitcast.478), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block3_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:01.470420: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.46 = (f32[26,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,256,18,18]{3,2,1,0} %bitcast.498, f32[512,256,3,3]{3,2,1,0}
%bitcast.505, f32[512]{0} %bitcast.507), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block4_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:01.791287: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.47 = (f32[26,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,512,18,18]{3,2,1,0} %bitcast.512, f32[512,512,3,3]{3,2,1,0}
%bitcast.519, f32[512]{0} %bitcast.521), window={size=3x3 pad=1_1x1_1},
```

```
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block4_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:02.396564: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.49 = (f32[26,512,9,9]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,512,9,9]{3,2,1,0} %bitcast.541, f32[512,512,3,3]{3,2,1,0}
%bitcast.548, f32[512]{0} %bitcast.550), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block5_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}

1/1             5s 5s/step

2025-06-11 19:32:02.969148: I tensorflow/core/framework/local_rendezvous.cc:407]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence

1/1             0s 93ms/step
1/1             0s 91ms/step
1/1             0s 92ms/step
1/1             0s 91ms/step
1/1             0s 88ms/step
1/1             0s 92ms/step
1/1             0s 96ms/step
1/1             0s 93ms/step
1/1             0s 92ms/step
1/1             0s 91ms/step
1/1             0s 90ms/step
1/1             0s 93ms/step
1/1             0s 92ms/step
1/1             0s 88ms/step
1/1             0s 95ms/step
1/1             0s 91ms/step
1/1             0s 91ms/step
1/1             0s 87ms/step
1/1             0s 94ms/step
1/1             0s 89ms/step
1/1             0s 95ms/step
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1/1             0s 98ms/step
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1/1             0s 96ms/step
1/1             0s 91ms/step
1/1             0s 92ms/step
1/1             0s 93ms/step
1/1             0s 95ms/step
1/1             0s 90ms/step
1/1             0s 93ms/step
1/1             0s 90ms/step
1/1             0s 93ms/step
1/1             0s 95ms/step
1/1             0s 102ms/step
1/1             0s 97ms/step
1/1             0s 99ms/step
1/1             0s 93ms/step
1/1             0s 95ms/step
1/1             0s 92ms/step
1/1             0s 95ms/step
1/1             0s 99ms/step
1/1             0s 101ms/step
1/1             0s 100ms/step
1/1             0s 92ms/step
1/1             0s 97ms/step
1/1             0s 101ms/step
1/1             0s 96ms/step
1/1             0s 95ms/step
1/1             0s 91ms/step
1/1             0s 99ms/step
1/1             0s 95ms/step
1/1             0s 98ms/step
1/1             0s 93ms/step
1/1             0s 98ms/step
1/1             0s 91ms/step
1/1             0s 96ms/step
1/1             0s 93ms/step
1/1             0s 98ms/step
1/1             0s 94ms/step
1/1             0s 92ms/step
1/1             0s 97ms/step
1/1             0s 95ms/step
1/1             0s 96ms/step
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1/1             0s 90ms/step
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1/1             0s 92ms/step
1/1             0s 91ms/step
1/1             0s 94ms/step
1/1             0s 92ms/step
1/1             0s 95ms/step
1/1             0s 90ms/step
1/1             0s 94ms/step
1/1             0s 90ms/step
1/1             0s 92ms/step
1/1             0s 90ms/step
1/1             0s 93ms/step
1/1             0s 97ms/step
1/1             0s 96ms/step
1/1             0s 96ms/step
1/1             0s 95ms/step
1/1             0s 92ms/step
1/1             0s 94ms/step
1/1             0s 94ms/step
1/1             0s 91ms/step
1/1             0s 92ms/step
1/1             0s 92ms/step
1/1             0s 94ms/step
```

```
2025-06-11 19:32:18.072499: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.39 = (f32[24,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,3,150,150]{3,2,1,0} %bitcast.396, f32[64,3,3,3]{3,2,1,0}
%bitcast.403, f32[64]{0} %bitcast.405), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block1_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:18.297624: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.40 = (f32[24,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,64,150,150]{3,2,1,0} %bitcast.410, f32[64,64,3,3]{3,2,1,0}
%bitcast.417, f32[64]{0} %bitcast.419), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block1_conv2_1/convolution"
```

source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:19.077282: I external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-activation.41 = (f32[24,128,75,75]{3,2,1,0}, u8[0]{0}) custom-call(f32[24,64,75,75]{3,2,1,0} %bitcast.426, f32[128,64,3,3]{3,2,1,0} %bitcast.433, f32[128]{0} %bitcast.435), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type="Conv2D" op_name="vgg16_1/block2_conv1_1/convolution" source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:19.614220: I external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-activation.42 = (f32[24,128,75,75]{3,2,1,0}, u8[0]{0}) custom-call(f32[24,128,75,75]{3,2,1,0} %bitcast.440, f32[128,128,3,3]{3,2,1,0} %bitcast.447, f32[128]{0} %bitcast.449), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type="Conv2D" op_name="vgg16_1/block2_conv2_1/convolution" source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:20.204081: I external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-activation.43 = (f32[24,256,37,37]{3,2,1,0}, u8[0]{0}) custom-call(f32[24,128,37,37]{3,2,1,0} %bitcast.455, f32[256,128,3,3]{3,2,1,0} %bitcast.462, f32[256]{0} %bitcast.464), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type="Conv2D" op_name="vgg16_1/block3_conv1_1/convolution" source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:20.552360: I

```
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.44 = (f32[24,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,256,37,37]{3,2,1,0} %bitcast.469, f32[256,256,3,3]{3,2,1,0}
%bitcast.476, f32[256]{0} %bitcast.478), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block3_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:23.544711: E
external/local_xla/xla/service/slow_operation_alarm.cc:73] Trying algorithm
eng15{k5=1,k6=0,k7=1,k10=8} for conv %cudnn-conv-bias-activation.44 =
(f32[24,256,37,37]{3,2,1,0}, u8[0]{0}) custom-call(f32[24,256,37,37]{3,2,1,0}
%bitcast.469, f32[256,256,3,3]{3,2,1,0} %bitcast.476, f32[256]{0} %bitcast.478),
window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block3_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false} is taking a while…
2025-06-11 19:32:23.545597: E
external/local_xla/xla/service/slow_operation_alarm.cc:140] The operation took
2.954946718s
Trying algorithm eng15{k5=1,k6=0,k7=1,k10=8} for conv %cudnn-conv-bias-
activation.44 = (f32[24,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,256,37,37]{3,2,1,0} %bitcast.469, f32[256,256,3,3]{3,2,1,0}
%bitcast.476, f32[256]{0} %bitcast.478), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block3_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false} is taking a while…
2025-06-11 19:32:24.121325: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.46 = (f32[24,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,256,18,18]{3,2,1,0} %bitcast.498, f32[512,256,3,3]{3,2,1,0}
%bitcast.505, f32[512]{0} %bitcast.507), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
```

```
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block4_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:24.462742: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.47 = (f32[24,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,512,18,18]{3,2,1,0} %bitcast.512, f32[512,512,3,3]{3,2,1,0}
%bitcast.519, f32[512]{0} %bitcast.521), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block4_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:32:25.122759: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.49 = (f32[24,512,9,9]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,512,9,9]{3,2,1,0} %bitcast.541, f32[512,512,3,3]{3,2,1,0}
%bitcast.548, f32[512]{0} %bitcast.550), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D" op_name="vgg16_1/block5_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}

1/1            8s 8s/step

2025-06-11 19:32:25.678946: I tensorflow/core/framework/local_rendezvous.cc:407]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence

1/1            0s 98ms/step
1/1            0s 92ms/step
1/1            0s 95ms/step
1/1            0s 96ms/step
1/1            0s 95ms/step
1/1            0s 94ms/step
1/1            0s 95ms/step
1/1            0s 96ms/step
```

```
1/1             0s 90ms/step
1/1             0s 95ms/step
1/1             0s 96ms/step
1/1             0s 92ms/step
1/1             0s 97ms/step
1/1             0s 93ms/step
1/1             0s 95ms/step
1/1             0s 96ms/step
1/1             0s 94ms/step
1/1             0s 92ms/step
1/1             0s 92ms/step
1/1             0s 90ms/step
1/1             0s 94ms/step
1/1             0s 91ms/step
1/1             0s 91ms/step
1/1             0s 94ms/step
1/1             0s 104ms/step
1/1             0s 90ms/step
1/1             0s 98ms/step
1/1             0s 98ms/step
1/1             0s 97ms/step
1/1             0s 88ms/step
1/1             0s 93ms/step
1/1             0s 92ms/step
1/1             0s 89ms/step
1/1             0s 89ms/step
1/1             0s 94ms/step
1/1             0s 89ms/step
1/1             0s 95ms/step
1/1             0s 93ms/step
1/1             0s 95ms/step
1/1             0s 101ms/step
1/1             0s 90ms/step
1/1             0s 93ms/step
1/1             0s 93ms/step
1/1             0s 95ms/step
1/1             0s 92ms/step
1/1             0s 92ms/step
1/1             0s 94ms/step
1/1             0s 88ms/step
1/1             0s 95ms/step
1/1             0s 94ms/step
1/1             0s 91ms/step
1/1             0s 94ms/step
1/1             0s 94ms/step
1/1             0s 88ms/step
1/1             0s 92ms/step
1/1             0s 93ms/step
```

```
1/1             0s 89ms/step
1/1             0s 89ms/step
1/1             0s 93ms/step
1/1             0s 89ms/step
1/1             0s 96ms/step
1/1             0s 97ms/step
1/1             0s 93ms/step
1/1             0s 91ms/step
1/1             0s 103ms/step
1/1             0s 96ms/step
1/1             0s 90ms/step
1/1             0s 90ms/step
1/1             0s 97ms/step
1/1             0s 92ms/step
1/1             0s 96ms/step
1/1             0s 92ms/step
1/1             0s 98ms/step
1/1             0s 94ms/step
1/1             0s 94ms/step
1/1             0s 93ms/step
1/1             0s 96ms/step
1/1             0s 95ms/step
1/1             0s 92ms/step
1/1             0s 90ms/step
1/1             0s 96ms/step
1/1             0s 93ms/step
1/1             0s 92ms/step
1/1             0s 93ms/step
1/1             0s 100ms/step
1/1             0s 93ms/step
1/1             0s 98ms/step
1/1             0s 99ms/step
1/1             0s 97ms/step
1/1             0s 94ms/step
1/1             0s 92ms/step
1/1             0s 91ms/step
1/1             0s 90ms/step
1/1             0s 79ms/step
```

3.2 Guardar features e labels dos conjuntos de dados

[10]:
```
np.save('modelT_train_features.npy', train_features)
np.save('modelT_train_labels.npy', train_labels)
np.save('modelT_val_features.npy', val_features)
np.save('modelT_val_labels.npy', val_labels)
np.save('modelT_test_features.npy', test_features)
np.save('modelT_test_labels.npy', test_labels)
```

```
train_features = np.load('modelT_train_features.npy')
train_labels = np.load('modelT_train_labels.npy')
val_features = np.load('modelT_val_features.npy')
val_labels = np.load('modelT_val_labels.npy')
test_features = np.load('modelT_test_features.npy')
test_labels = np.load('modelT_test_labels.npy')
```

3.3 Criação da CNN para VGG16

Este bloco define a head da rede que será acoplada ao VGG16 pré-treinado, assumindo que a saída do VGG16 tem forma (4, 4, 512). A arquitetura inclui uma camada Flatten, uma camada densa com 256 unidades e ativação ReLU, seguida de Dropout para reduzir overfitting, e termina com uma camada Dense com ativação softmax para realizar a classificação multiclasse.

[11]:
```
inputs = keras.Input(shape=(4, 4, 512))
x = layers.Flatten()(inputs)
x = layers.Dense(256, activation="relu")(x)
x = layers.Dropout(0.5)(x)
outputs = layers.Dense(len(class_names), activation="softmax")(x)
model = keras.Model(inputs, outputs)
```

3.4 Compilação da CNN

Compilação da CNN utilizando a loss **KLDivergence** e o optimizer **RMSprop**.

[12]:
```
model.compile(optimizer=tf.keras.optimizers.RMSprop(learning_rate=1e-4),␣
↪loss='categorical_crossentropy', metrics=['accuracy'])
```

3.5 Definição do callback

Definição de um callback que guarda automaticamente o modelo com a menor perda (loss) de validação durante o treino.

[13]:
```
checkpoint_filepath = 'modelT_featureExtraction_head.keras'
model_checkpoint_callback = keras.callbacks.ModelCheckpoint(
    filepath=checkpoint_filepath,
    monitor='val_loss',
    save_best_only=True)
```

3.6 Treino da CNN

Treino do modelo durante 50 épocas com os features e labels extraídos.

[14]:
```
print('Is eager: ', tf.executing_eagerly())
history = model.fit(
    train_features, train_labels,
    epochs=50,
    validation_data=(val_features, val_labels),
```

```
    callbacks=[model_checkpoint_callback])
```

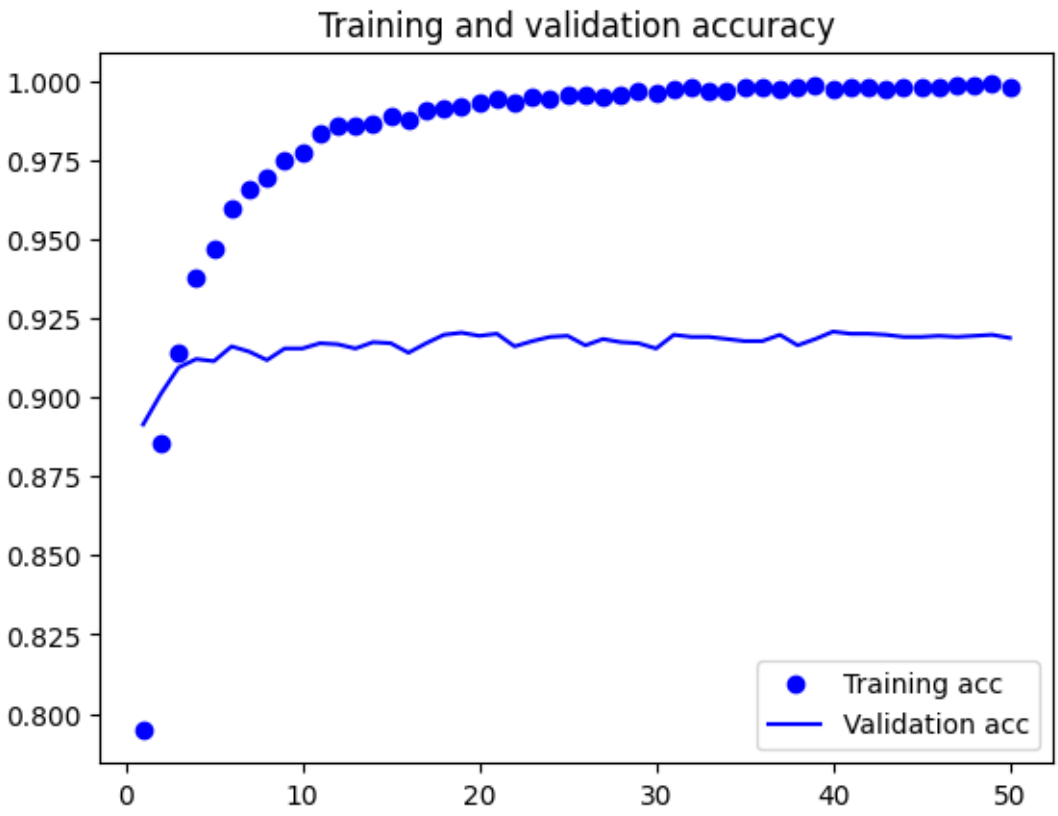
```
Is eager:  True
Epoch 1/50
345/345             6s 12ms/step -
accuracy: 0.7081 - loss: 4.2651 - val_accuracy: 0.8913 - val_loss: 0.8341
Epoch 2/50
345/345             2s 7ms/step -
accuracy: 0.8830 - loss: 0.8522 - val_accuracy: 0.9010 - val_loss: 0.5949
Epoch 3/50
345/345             5s 15ms/step -
accuracy: 0.9132 - loss: 0.4457 - val_accuracy: 0.9093 - val_loss: 0.5856
Epoch 4/50
345/345             2s 7ms/step -
accuracy: 0.9392 - loss: 0.2887 - val_accuracy: 0.9120 - val_loss: 0.5677
Epoch 5/50
345/345             2s 6ms/step -
accuracy: 0.9446 - loss: 0.2248 - val_accuracy: 0.9113 - val_loss: 0.6040
Epoch 6/50
345/345             2s 7ms/step -
accuracy: 0.9618 - loss: 0.1875 - val_accuracy: 0.9160 - val_loss: 0.6353
Epoch 7/50
345/345             2s 7ms/step -
accuracy: 0.9660 - loss: 0.1452 - val_accuracy: 0.9143 - val_loss: 0.6442
Epoch 8/50
345/345             3s 7ms/step -
accuracy: 0.9694 - loss: 0.1130 - val_accuracy: 0.9117 - val_loss: 0.6856
Epoch 9/50
345/345             3s 8ms/step -
accuracy: 0.9793 - loss: 0.0765 - val_accuracy: 0.9153 - val_loss: 0.7188
Epoch 10/50
345/345             2s 7ms/step -
accuracy: 0.9781 - loss: 0.0939 - val_accuracy: 0.9153 - val_loss: 0.7418
Epoch 11/50
345/345             2s 7ms/step -
accuracy: 0.9846 - loss: 0.0654 - val_accuracy: 0.9170 - val_loss: 0.8015
Epoch 12/50
345/345             2s 7ms/step -
accuracy: 0.9868 - loss: 0.0564 - val_accuracy: 0.9167 - val_loss: 0.8078
Epoch 13/50
345/345             2s 7ms/step -
accuracy: 0.9861 - loss: 0.0574 - val_accuracy: 0.9153 - val_loss: 0.8153
Epoch 14/50
345/345             2s 6ms/step -
accuracy: 0.9869 - loss: 0.0520 - val_accuracy: 0.9173 - val_loss: 0.8200
Epoch 15/50
345/345             2s 7ms/step -
accuracy: 0.9880 - loss: 0.0473 - val_accuracy: 0.9170 - val_loss: 0.8699
```

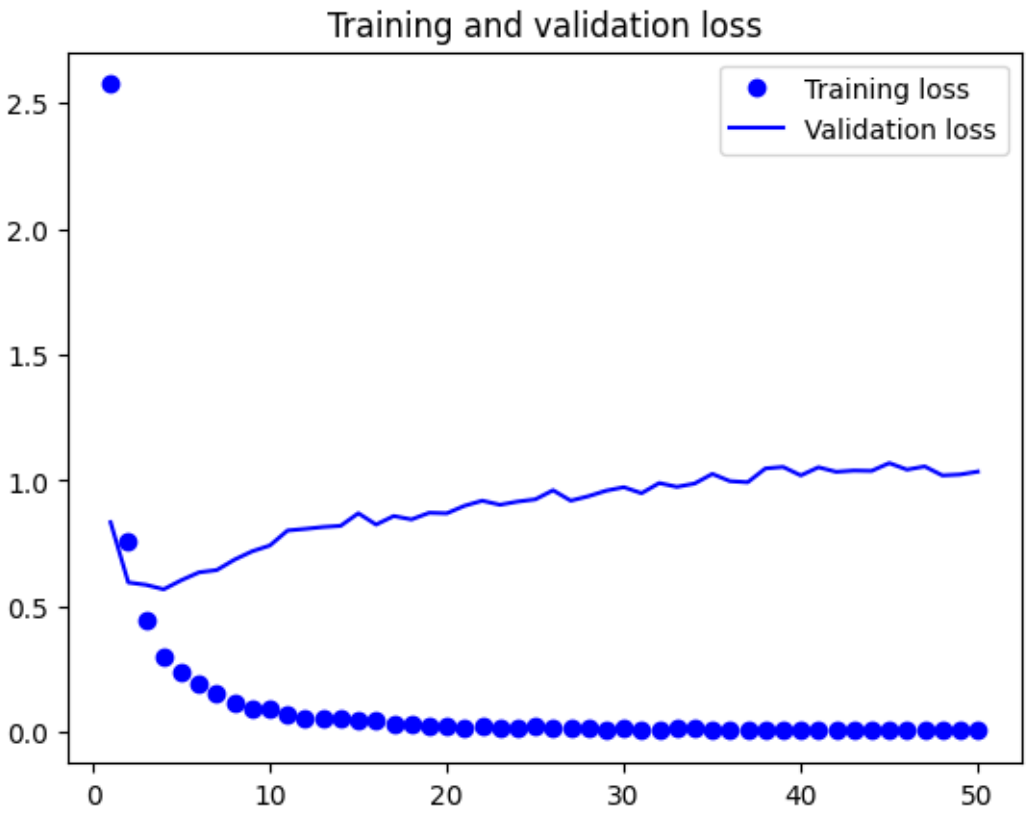
```
Epoch 16/50
345/345             5s 15ms/step -
accuracy: 0.9875 - loss: 0.0480 - val_accuracy: 0.9140 - val_loss: 0.8249
Epoch 17/50
345/345             2s 7ms/step -
accuracy: 0.9917 - loss: 0.0287 - val_accuracy: 0.9170 - val_loss: 0.8589
Epoch 18/50
345/345             2s 7ms/step -
accuracy: 0.9919 - loss: 0.0289 - val_accuracy: 0.9197 - val_loss: 0.8454
Epoch 19/50
345/345             3s 8ms/step -
accuracy: 0.9928 - loss: 0.0203 - val_accuracy: 0.9203 - val_loss: 0.8717
Epoch 20/50
345/345             3s 8ms/step -
accuracy: 0.9940 - loss: 0.0169 - val_accuracy: 0.9193 - val_loss: 0.8697
Epoch 21/50
345/345             3s 8ms/step -
accuracy: 0.9948 - loss: 0.0192 - val_accuracy: 0.9200 - val_loss: 0.8996
Epoch 22/50
345/345             3s 8ms/step -
accuracy: 0.9936 - loss: 0.0215 - val_accuracy: 0.9160 - val_loss: 0.9197
Epoch 23/50
345/345             3s 8ms/step -
accuracy: 0.9956 - loss: 0.0165 - val_accuracy: 0.9177 - val_loss: 0.9036
Epoch 24/50
345/345             3s 8ms/step -
accuracy: 0.9943 - loss: 0.0192 - val_accuracy: 0.9190 - val_loss: 0.9163
Epoch 25/50
345/345             3s 8ms/step -
accuracy: 0.9951 - loss: 0.0251 - val_accuracy: 0.9193 - val_loss: 0.9252
Epoch 26/50
345/345             3s 8ms/step -
accuracy: 0.9947 - loss: 0.0208 - val_accuracy: 0.9163 - val_loss: 0.9613
Epoch 27/50
345/345             3s 8ms/step -
accuracy: 0.9958 - loss: 0.0159 - val_accuracy: 0.9183 - val_loss: 0.9199
Epoch 28/50
345/345             6s 17ms/step -
accuracy: 0.9963 - loss: 0.0115 - val_accuracy: 0.9173 - val_loss: 0.9376
Epoch 29/50
345/345             3s 8ms/step -
accuracy: 0.9961 - loss: 0.0148 - val_accuracy: 0.9170 - val_loss: 0.9597
Epoch 30/50
345/345             3s 8ms/step -
accuracy: 0.9969 - loss: 0.0119 - val_accuracy: 0.9153 - val_loss: 0.9734
Epoch 31/50
345/345             3s 8ms/step -
accuracy: 0.9973 - loss: 0.0150 - val_accuracy: 0.9197 - val_loss: 0.9495
```

```
Epoch 32/50
345/345             3s 8ms/step -
accuracy: 0.9983 - loss: 0.0055 - val_accuracy: 0.9190 - val_loss: 0.9899
Epoch 33/50
345/345             3s 8ms/step -
accuracy: 0.9961 - loss: 0.0203 - val_accuracy: 0.9190 - val_loss: 0.9748
Epoch 34/50
345/345             3s 8ms/step -
accuracy: 0.9968 - loss: 0.0108 - val_accuracy: 0.9183 - val_loss: 0.9880
Epoch 35/50
345/345             3s 9ms/step -
accuracy: 0.9984 - loss: 0.0080 - val_accuracy: 0.9177 - val_loss: 1.0262
Epoch 36/50
345/345             3s 8ms/step -
accuracy: 0.9980 - loss: 0.0095 - val_accuracy: 0.9177 - val_loss: 0.9974
Epoch 37/50
345/345             3s 8ms/step -
accuracy: 0.9982 - loss: 0.0103 - val_accuracy: 0.9197 - val_loss: 0.9931
Epoch 38/50
345/345             3s 8ms/step -
accuracy: 0.9983 - loss: 0.0064 - val_accuracy: 0.9163 - val_loss: 1.0480
Epoch 39/50
345/345             3s 8ms/step -
accuracy: 0.9976 - loss: 0.0131 - val_accuracy: 0.9183 - val_loss: 1.0539
Epoch 40/50
345/345             6s 17ms/step -
accuracy: 0.9972 - loss: 0.0106 - val_accuracy: 0.9207 - val_loss: 1.0202
Epoch 41/50
345/345             3s 8ms/step -
accuracy: 0.9974 - loss: 0.0104 - val_accuracy: 0.9200 - val_loss: 1.0526
Epoch 42/50
345/345             3s 9ms/step -
accuracy: 0.9980 - loss: 0.0108 - val_accuracy: 0.9200 - val_loss: 1.0345
Epoch 43/50
345/345             4s 10ms/step -
accuracy: 0.9970 - loss: 0.0125 - val_accuracy: 0.9197 - val_loss: 1.0396
Epoch 44/50
345/345             3s 8ms/step -
accuracy: 0.9978 - loss: 0.0055 - val_accuracy: 0.9190 - val_loss: 1.0382
Epoch 45/50
345/345             3s 9ms/step -
accuracy: 0.9978 - loss: 0.0076 - val_accuracy: 0.9190 - val_loss: 1.0693
Epoch 46/50
345/345             3s 8ms/step -
accuracy: 0.9978 - loss: 0.0107 - val_accuracy: 0.9193 - val_loss: 1.0433
Epoch 47/50
345/345             3s 8ms/step -
accuracy: 0.9983 - loss: 0.0101 - val_accuracy: 0.9190 - val_loss: 1.0560
```

```
Epoch 48/50
345/345             3s 8ms/step -
accuracy: 0.9985 - loss: 0.0053 - val_accuracy: 0.9193 - val_loss: 1.0202
Epoch 49/50
345/345             3s 9ms/step -
accuracy: 0.9989 - loss: 0.0040 - val_accuracy: 0.9197 - val_loss: 1.0239
Epoch 50/50
345/345             6s 17ms/step -
accuracy: 0.9978 - loss: 0.0061 - val_accuracy: 0.9187 - val_loss: 1.0354
```

[15]:
```
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs = range(1, len(acc) + 1)
plt.plot(epochs, acc, 'bo', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Training and validation accuracy')
plt.legend()
plt.figure()
plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
plt.show()
```


Training and validation accuracy
1.000
0.975
0.950
0.925
0.900
0.875
0.850
0.825
0.800
0
10
20
30
40
50
Training acc
Validation acc



3.7 Criação da CNN com vgg16

Criação do modelo completo combinando o VGG16 pré-treinado (conv_base) com o modelo definido anteriormente.

[16]:
```
inputs = keras.Input(shape=(150, 150, 3))
x = keras.applications.vgg16.preprocess_input(inputs)
x = conv_base(x)
outputs = model(x)
full_model = keras.Model(inputs, outputs)
```

3.8 Compilação da CNN

Compilação da CNN utilizando a loss **categorical crossentropy** e o optimizer **RMSprop**.

[17]:
```
full_model.compile(optimizer=tf.keras.optimizers.RMSprop(learning_rate=1e-4),␣
↪loss='categorical_crossentropy', metrics=['accuracy'])
```

3.9 Guardar modelo

[18]:
```
full_model.save('modelT_featureExtraction_full.keras')
```

3.10 Carregamento do modelo e validação

Carregamento e avaliação do modelo através do valor da accuracy.

[10]:
```
full_model = keras.models.load_model('modelT_featureExtraction_full.keras')
val_loss, val_acc = full_model.evaluate(validation_dataset)
print('val_acc:', val_acc)
```

```
/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/keras/src/saving/saving_lib.py:802: UserWarning: Skipping variable
loading for optimizer 'rmsprop', because it has 32 variables whereas the saved
optimizer has 0 variables.
  saveable.load_own_variables(weights_store.get(inner_path))
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
I0000 00:00:1749766223.526179     649 service.cc:152] XLA service 0x72486c006e00
initialized for platform CUDA (this does not guarantee that XLA will be used).
Devices:
I0000 00:00:1749766223.526245     649 service.cc:160]   StreamExecutor device
(0): NVIDIA GeForce GTX 1070, Compute Capability 6.1
2025-06-12 23:10:23.583936: I
tensorflow/compiler/mlir/tensorflow/utils/dump_mlir_util.cc:269] disabling MLIR
crash reproducer, set env var `MLIR_CRASH_REPRODUCER_DIRECTORY` to enable.
2025-06-12 23:10:24.182179: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.39 = (f32[32,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,3,150,150]{3,2,1,0} %bitcast.850, f32[64,3,3,3]{3,2,1,0}
%bitcast.857, f32[64]{0} %bitcast.859), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:24.582144: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.40 = (f32[32,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,64,150,150]{3,2,1,0} %bitcast.864, f32[64,64,3,3]{3,2,1,0}
%bitcast.871, f32[64]{0} %bitcast.873), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
```

custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:25.705102: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.41 = (f32[32,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,64,75,75]{3,2,1,0} %bitcast.881, f32[128,64,3,3]{3,2,1,0}
%bitcast.888, f32[128]{0} %bitcast.890), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:26.534953: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.42 = (f32[32,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
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%bitcast.902, f32[128]{0} %bitcast.904), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:27.458633: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.43 = (f32[32,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
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%bitcast.917, f32[256]{0} %bitcast.919), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
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op_name="functional_1_1/vgg16_1/block3_conv1_1/convolution"

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external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
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%bitcast.931, f32[256]{0} %bitcast.933), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
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packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:28.894187: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.46 = (f32[32,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,256,18,18]{3,2,1,0} %bitcast.953, f32[512,256,3,3]{3,2,1,0}
%bitcast.960, f32[512]{0} %bitcast.962), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:29.380461: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.47 = (f32[32,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,512,18,18]{3,2,1,0} %bitcast.967, f32[512,512,3,3]{3,2,1,0}
%bitcast.974, f32[512]{0} %bitcast.976), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi

g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:30.256128: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.49 = (f32[32,512,9,9]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,512,9,9]{3,2,1,0} %bitcast.996, f32[512,512,3,3]{3,2,1,0}
%bitcast.1003, f32[512]{0} %bitcast.1005), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
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op_name="functional_1_1/vgg16_1/block5_conv1_1/convolution"
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packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
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g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}

2/94 **7s** 78ms/step - accuracy:
0.8828 - loss: 1.9134

I0000 00:00:1749766231.221100 649 device_compiler.h:188] Compiled cluster
using XLA! This line is logged at most once for the lifetime of the process.

93/94 **0s** 76ms/step -
accuracy: 0.9121 - loss: 1.2389

2025-06-12 23:10:38.675693: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.39 = (f32[24,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,3,150,150]{3,2,1,0} %bitcast.850, f32[64,3,3,3]{3,2,1,0}
%bitcast.857, f32[64]{0} %bitcast.859), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:38.940932: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.40 = (f32[24,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,64,150,150]{3,2,1,0} %bitcast.864, f32[64,64,3,3]{3,2,1,0}
%bitcast.871, f32[64]{0} %bitcast.873), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",

metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv2_1/convolution"
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packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:39.856554: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.41 = (f32[24,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,64,75,75]{3,2,1,0} %bitcast.881, f32[128,64,3,3]{3,2,1,0}
%bitcast.888, f32[128]{0} %bitcast.890), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:40.536158: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.42 = (f32[24,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,128,75,75]{3,2,1,0} %bitcast.895, f32[128,128,3,3]{3,2,1,0}
%bitcast.902, f32[128]{0} %bitcast.904), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:41.273315: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.43 = (f32[24,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,128,37,37]{3,2,1,0} %bitcast.910, f32[256,128,3,3]{3,2,1,0}
%bitcast.917, f32[256]{0} %bitcast.919), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block3_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-

packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:41.711503: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.44 = (f32[24,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,256,37,37]{3,2,1,0} %bitcast.924, f32[256,256,3,3]{3,2,1,0}
%bitcast.931, f32[256]{0} %bitcast.933), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block3_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:42.392680: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.46 = (f32[24,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,256,18,18]{3,2,1,0} %bitcast.953, f32[512,256,3,3]{3,2,1,0}
%bitcast.960, f32[512]{0} %bitcast.962), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:42.784604: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.47 = (f32[24,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,512,18,18]{3,2,1,0} %bitcast.967, f32[512,512,3,3]{3,2,1,0}
%bitcast.974, f32[512]{0} %bitcast.976), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr

```
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:10:43.504796: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.49 = (f32[24,512,9,9]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,512,9,9]{3,2,1,0} %bitcast.996, f32[512,512,3,3]{3,2,1,0}
%bitcast.1003, f32[512]{0} %bitcast.1005), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block5_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
```

```
94/94            21s 140ms/step -
accuracy: 0.9122 - loss: 1.2346
val_acc: 0.918666660785675
```

3.11 Computing the model output for one image

[20]:
```python
from PIL import Image
img_path = 'Dataset/archive/seg_test/sea/20072.jpg'

img = tf.keras.preprocessing.image.load_img(
    img_path,
    target_size=(150, 150),
    interpolation='bilinear'
)

plt.imshow(img)
plt.axis('off')
plt.title("Imagem de Teste")
plt.show()

img_array = tf.keras.preprocessing.image.img_to_array(img)
img_array = tf.expand_dims(img_array, 0)

result = full_model.predict(img_array)

class_names = ['buildings', 'forest', 'glacier', 'mountain', 'sea', 'street']
print("Probabilidades por classe:")
for i, prob in enumerate(result[0]):
    print(f"{class_names[i]:>10s}: {prob:.4f}")

predicted_class = np.argmax(result)
```

```
print(f"\nClasse prevista: {class_names[predicted_class]}␣
↪({result[0][predicted_class]:.4f})")
```


```
2025-06-11 19:35:30.338582: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.39 = (f32[1,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,3,150,150]{3,2,1,0} %bitcast.543, f32[64,3,3,3]{3,2,1,0}
%bitcast.550, f32[64]{0} %bitcast.552), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:35:30.421542: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.40 = (f32[1,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
```

```
call(f32[1,64,150,150]{3,2,1,0} %bitcast.557, f32[64,64,3,3]{3,2,1,0}
%bitcast.564, f32[64]{0} %bitcast.566), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:35:30.483129: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.41 = (f32[1,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,64,75,75]{3,2,1,0} %bitcast.573, f32[128,64,3,3]{3,2,1,0}
%bitcast.580, f32[128]{0} %bitcast.582), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:35:30.559070: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.42 = (f32[1,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,128,75,75]{3,2,1,0} %bitcast.587, f32[128,128,3,3]{3,2,1,0}
%bitcast.594, f32[128]{0} %bitcast.596), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:35:30.607274: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.43 = (f32[1,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,128,37,37]{3,2,1,0} %bitcast.602, f32[256,128,3,3]{3,2,1,0}
%bitcast.609, f32[256]{0} %bitcast.611), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
```

custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block3_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:35:30.679689: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.44 = (f32[1,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,256,37,37]{3,2,1,0} %bitcast.616, f32[256,256,3,3]{3,2,1,0}
%bitcast.623, f32[256]{0} %bitcast.625), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block3_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:35:30.741615: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.46 = (f32[1,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,256,18,18]{3,2,1,0} %bitcast.645, f32[512,256,3,3]{3,2,1,0}
%bitcast.652, f32[512]{0} %bitcast.654), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:35:30.824102: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.47 = (f32[1,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,512,18,18]{3,2,1,0} %bitcast.659, f32[512,512,3,3]{3,2,1,0}
%bitcast.666, f32[512]{0} %bitcast.668), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv2_1/convolution"

```
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 19:35:30.913396: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.49 = (f32[1,512,9,9]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,512,9,9]{3,2,1,0} %bitcast.688, f32[512,512,3,3]{3,2,1,0}
%bitcast.695, f32[512]{0} %bitcast.697), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block5_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
```

```
1/1             1s 1s/step
Probabilidades por classe:
 buildings: 0.0000
    forest: 0.0000
   glacier: 0.0000
  mountain: 0.0000
       sea: 1.0000
    street: 0.0000

Classe prevista: sea (1.0000)
```

4 Feature extraction with data augmentation

[21]:
```
conv_base_DA = VGG16(weights="imagenet", include_top=False)
conv_base_DA.trainable = False
```

4.1 Data augmentation

Criação de data augmentation que aplica transformações aleatórias às imagens durante o treino, incluindo inversão horizontal, pequenas rotações e zoom, com o objetivo de aumentar a variabilidade dos dados e melhorar a generalização do modelo.

[22]:
```
data_augmentation = keras.Sequential([
     layers.RandomFlip("horizontal"),
    layers.RandomRotation(0.1),
    layers.RandomZoom(0.2),
```

```
])
```

4.2 Criação da CNN

Criação do modelo completo com base no VGG16 pré-treinado, incluindo uma etapa inicial de data augmentation, seguida do pré-processamento específico do VGG16. A saída do conv_base_DA é passada por camadas Flatten, Dense e Dropout, terminando com uma camada softmax para classificação multiclasse.

[23]:
```
inputs = keras.Input(shape=(150, 150, 3))
x = data_augmentation(inputs)
x = keras.applications.vgg16.preprocess_input(x)
x = conv_base_DA(x)
x = layers.Flatten()(x)
x = layers.Dense(256, activation="relu")(x)
x = layers.Dropout(0.5)(x)
outputs = layers.Dense(len(class_names), activation="softmax")(x)
model_DA = keras.Model(inputs, outputs)
```

4.3 Compilação da CNN

Compilação da CNN utilizando a loss **categorical crossentropy** e o optimizer **RMSprop**.

[24]:
```
model_DA.compile(optimizer=tf.keras.optimizers.RMSprop(learning_rate=1e-4),␣
↪loss='categorical_crossentropy', metrics=['accuracy'])
```

4.4 Definição do callback

Definição de um callback que guarda automaticamente o modelo com a menor perda (loss) de validação durante o treino.

[25]:
```
checkpoint_filepath_DA = 'modelT_featureExtraction_DataAugmentation.keras'
model_checkpoint_callback_DA = keras.callbacks.ModelCheckpoint(
    filepath=checkpoint_filepath_DA,
    monitor='val_loss',
    save_best_only=True)
```

4.5 Treino da CNN

Treino do modelo durante 50 épocas com os features e labels extraídos.

[26]:
```
tf.config.run_functions_eagerly(True)
print('Is eager: ', tf.executing_eagerly())
history_DA = model_DA.fit(
train_dataset,
epochs=50,
validation_data=validation_dataset,
callbacks=[model_checkpoint_callback_DA])
```

```
Is eager:  True
Epoch 1/50
345/345             147s 409ms/step -
accuracy: 0.6143 - loss: 4.5441 - val_accuracy: 0.8830 - val_loss: 0.7638
Epoch 2/50
345/345             137s 396ms/step -
accuracy: 0.8145 - loss: 0.9861 - val_accuracy: 0.8937 - val_loss: 0.5870
Epoch 3/50
345/345             138s 400ms/step -
accuracy: 0.8339 - loss: 0.7175 - val_accuracy: 0.8953 - val_loss: 0.5690
Epoch 4/50
345/345             138s 399ms/step -
accuracy: 0.8519 - loss: 0.6364 - val_accuracy: 0.8963 - val_loss: 0.5878
Epoch 5/50
345/345             138s 399ms/step -
accuracy: 0.8654 - loss: 0.5850 - val_accuracy: 0.9030 - val_loss: 0.5761
Epoch 6/50
345/345             138s 400ms/step -
accuracy: 0.8784 - loss: 0.5108 - val_accuracy: 0.9063 - val_loss: 0.5514
Epoch 7/50
345/345             132s 382ms/step -
accuracy: 0.8838 - loss: 0.5247 - val_accuracy: 0.9067 - val_loss: 0.5605
Epoch 8/50
345/345             135s 391ms/step -
accuracy: 0.8873 - loss: 0.5156 - val_accuracy: 0.9083 - val_loss: 0.5795
Epoch 9/50
345/345             134s 389ms/step -
accuracy: 0.8919 - loss: 0.4832 - val_accuracy: 0.9063 - val_loss: 0.6153
Epoch 10/50
345/345             134s 388ms/step -
accuracy: 0.8919 - loss: 0.4787 - val_accuracy: 0.9050 - val_loss: 0.6044
Epoch 11/50
345/345             134s 388ms/step -
accuracy: 0.8983 - loss: 0.4317 - val_accuracy: 0.9073 - val_loss: 0.6219
Epoch 12/50
345/345             131s 380ms/step -
accuracy: 0.8975 - loss: 0.4371 - val_accuracy: 0.9090 - val_loss: 0.6508
Epoch 13/50
345/345             134s 389ms/step -
accuracy: 0.9037 - loss: 0.4240 - val_accuracy: 0.9117 - val_loss: 0.6752
Epoch 14/50
345/345             134s 388ms/step -
accuracy: 0.9029 - loss: 0.4304 - val_accuracy: 0.9140 - val_loss: 0.6778
Epoch 15/50
345/345             135s 391ms/step -
accuracy: 0.9114 - loss: 0.3854 - val_accuracy: 0.9107 - val_loss: 0.6943
Epoch 16/50
345/345             134s 389ms/step -
```

```
accuracy: 0.9068 - loss: 0.3991 - val_accuracy: 0.9130 - val_loss: 0.6871
Epoch 17/50
345/345             131s 379ms/step -
accuracy: 0.9105 - loss: 0.4080 - val_accuracy: 0.9120 - val_loss: 0.7063
Epoch 18/50
345/345             130s 377ms/step -
accuracy: 0.9136 - loss: 0.3891 - val_accuracy: 0.9147 - val_loss: 0.7000
Epoch 19/50
345/345             130s 377ms/step -
accuracy: 0.9161 - loss: 0.3810 - val_accuracy: 0.9107 - val_loss: 0.7211
Epoch 20/50
345/345             127s 368ms/step -
accuracy: 0.9198 - loss: 0.3693 - val_accuracy: 0.9087 - val_loss: 0.7391
Epoch 21/50
345/345             130s 376ms/step -
accuracy: 0.9209 - loss: 0.3453 - val_accuracy: 0.9113 - val_loss: 0.7379
Epoch 22/50
345/345             130s 376ms/step -
accuracy: 0.9195 - loss: 0.3488 - val_accuracy: 0.9127 - val_loss: 0.7318
Epoch 23/50
345/345             127s 367ms/step -
accuracy: 0.9202 - loss: 0.3355 - val_accuracy: 0.9120 - val_loss: 0.7612
Epoch 24/50
345/345             130s 377ms/step -
accuracy: 0.9193 - loss: 0.3571 - val_accuracy: 0.9160 - val_loss: 0.7781
Epoch 25/50
345/345             130s 376ms/step -
accuracy: 0.9198 - loss: 0.3303 - val_accuracy: 0.9113 - val_loss: 0.7726
Epoch 26/50
345/345             127s 367ms/step -
accuracy: 0.9200 - loss: 0.3531 - val_accuracy: 0.9153 - val_loss: 0.7852
Epoch 27/50
345/345             130s 376ms/step -
accuracy: 0.9220 - loss: 0.3638 - val_accuracy: 0.9170 - val_loss: 0.7410
Epoch 28/50
345/345             130s 376ms/step -
accuracy: 0.9255 - loss: 0.3177 - val_accuracy: 0.9173 - val_loss: 0.7663
Epoch 29/50
345/345             127s 368ms/step -
accuracy: 0.9234 - loss: 0.3164 - val_accuracy: 0.9173 - val_loss: 0.7376
Epoch 30/50
345/345             130s 377ms/step -
accuracy: 0.9258 - loss: 0.3237 - val_accuracy: 0.9167 - val_loss: 0.7547
Epoch 31/50
345/345             130s 377ms/step -
accuracy: 0.9256 - loss: 0.3205 - val_accuracy: 0.9160 - val_loss: 0.7984
Epoch 32/50
345/345             127s 369ms/step -
```

```
accuracy: 0.9277 - loss: 0.2975 - val_accuracy: 0.9127 - val_loss: 0.7978
Epoch 33/50
345/345             130s 378ms/step -
accuracy: 0.9267 - loss: 0.3126 - val_accuracy: 0.9193 - val_loss: 0.8081
Epoch 34/50
345/345             130s 376ms/step -
accuracy: 0.9309 - loss: 0.2753 - val_accuracy: 0.9203 - val_loss: 0.7975
Epoch 35/50
345/345             127s 367ms/step -
accuracy: 0.9286 - loss: 0.3029 - val_accuracy: 0.9160 - val_loss: 0.8329
Epoch 36/50
345/345             130s 377ms/step -
accuracy: 0.9344 - loss: 0.2908 - val_accuracy: 0.9203 - val_loss: 0.8161
Epoch 37/50
345/345             130s 376ms/step -
accuracy: 0.9348 - loss: 0.2925 - val_accuracy: 0.9203 - val_loss: 0.8386
Epoch 38/50
345/345             127s 367ms/step -
accuracy: 0.9352 - loss: 0.2784 - val_accuracy: 0.9180 - val_loss: 0.8294
Epoch 39/50
345/345             130s 377ms/step -
accuracy: 0.9284 - loss: 0.3050 - val_accuracy: 0.9160 - val_loss: 0.8504
Epoch 40/50
345/345             131s 378ms/step -
accuracy: 0.9328 - loss: 0.2863 - val_accuracy: 0.9177 - val_loss: 0.8580
Epoch 41/50
345/345             127s 369ms/step -
accuracy: 0.9334 - loss: 0.2954 - val_accuracy: 0.9200 - val_loss: 0.8268
Epoch 42/50
345/345             130s 376ms/step -
accuracy: 0.9380 - loss: 0.2920 - val_accuracy: 0.9170 - val_loss: 0.8443
Epoch 43/50
345/345             130s 377ms/step -
accuracy: 0.9403 - loss: 0.2527 - val_accuracy: 0.9193 - val_loss: 0.8951
Epoch 44/50
345/345             127s 367ms/step -
accuracy: 0.9346 - loss: 0.2812 - val_accuracy: 0.9190 - val_loss: 0.8967
Epoch 45/50
345/345             130s 376ms/step -
accuracy: 0.9383 - loss: 0.2811 - val_accuracy: 0.9183 - val_loss: 0.8721
Epoch 46/50
345/345             130s 376ms/step -
accuracy: 0.9362 - loss: 0.2729 - val_accuracy: 0.9153 - val_loss: 0.9026
Epoch 47/50
345/345             127s 368ms/step -
accuracy: 0.9381 - loss: 0.2546 - val_accuracy: 0.9217 - val_loss: 0.9177
Epoch 48/50
345/345             130s 376ms/step -
```

```
accuracy: 0.9380 - loss: 0.2555 - val_accuracy: 0.9207 - val_loss: 0.9210
Epoch 49/50
345/345             130s 376ms/step -
accuracy: 0.9350 - loss: 0.3169 - val_accuracy: 0.9160 - val_loss: 0.9151
Epoch 50/50
345/345             127s 368ms/step -
accuracy: 0.9430 - loss: 0.2382 - val_accuracy: 0.9180 - val_loss: 0.9046
```

[ ]:
```
best_epoch = np.argmin(history.history['val_loss']) + 1
print(f"Melhor época (menor val_loss): {best_epoch}")
```

4.6 Carregamento do modelo e validação

Carregamento e avaliação do modelo através do valor da accuracy.

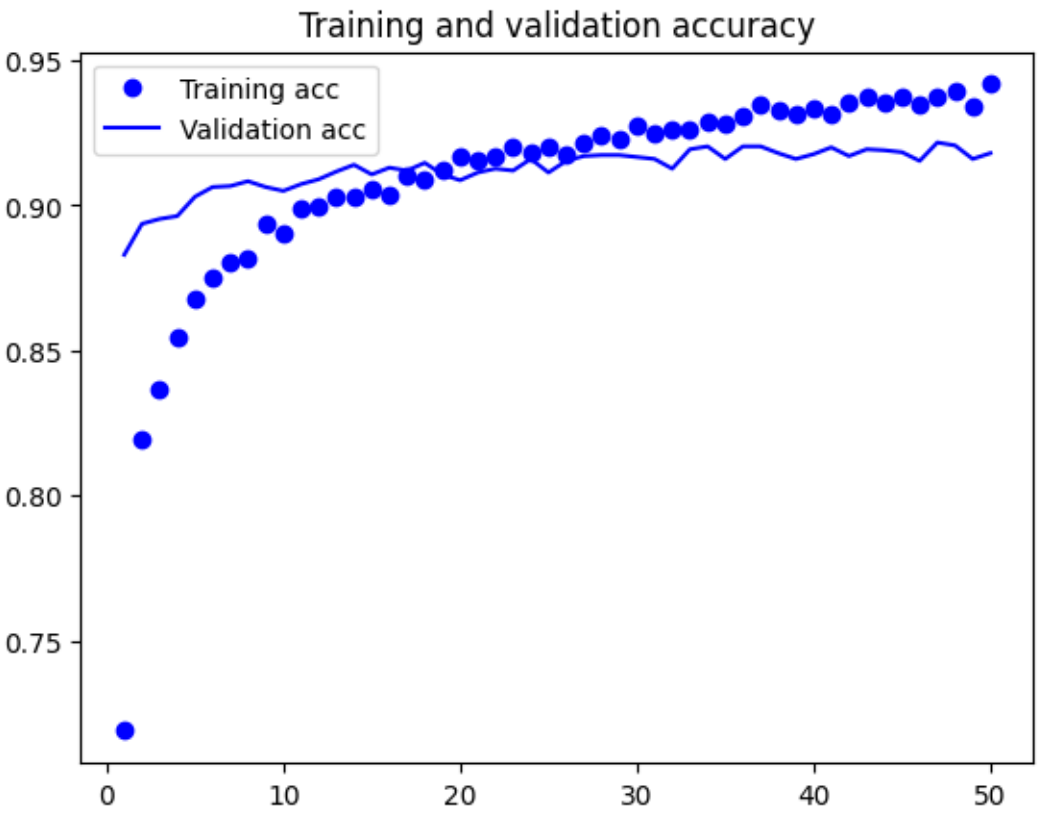
[7]:
```
model_DA = keras.models.load_model('modelT_featureExtraction_DataAugmentation.
↪keras')
val_loss, val_acc = model_DA.evaluate(validation_dataset)
print('val_acc:', val_acc)
```

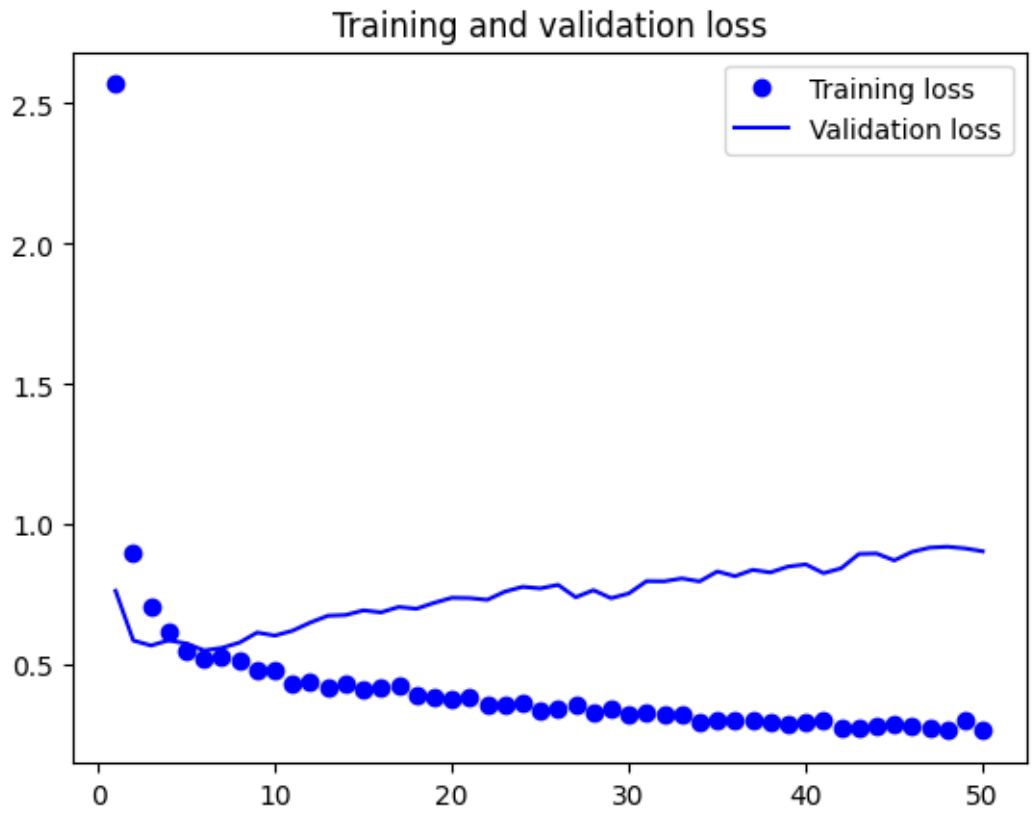
```
I0000 00:00:1749766180.475871     652 cuda_dnn.cc:529] Loaded cuDNN version
90300

94/94             15s 87ms/step -
accuracy: 0.9086 - loss: 0.5939
val_acc: 0.906333327293396
```

Representação gráfica dos valores da accuracy e da loss ao longo das épocas.

[29]:
```
acc = history_DA.history['accuracy']
val_acc = history_DA.history['val_accuracy']
loss = history_DA.history['loss']
val_loss = history_DA.history['val_loss']
epochs = range(1, len(acc) + 1)
plt.plot(epochs, acc, 'bo', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Training and validation accuracy')
plt.legend()
plt.figure()
plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
plt.show()
```


Training and validation accuracy
Training acc
Validation acc
0.95
0.90
0.85
0.80
0.75
0
10
20
30
40
50



[30]:
```
img_path = 'Dataset/archive/seg_test/sea/20072.jpg'

img = tf.keras.preprocessing.image.load_img(
    img_path,
    target_size=(150, 150),
    interpolation='bilinear'
)

plt.imshow(img)
plt.axis('off')
plt.title("Imagem de Teste")
plt.show()

img_array = tf.keras.preprocessing.image.img_to_array(img)
img_array = tf.expand_dims(img_array, 0)

result = model_DA.predict(img_array)

class_names = ['buildings', 'forest', 'glacier', 'mountain', 'sea', 'street']
print("Probabilidades por classe:")
for i, prob in enumerate(result[0]):
```

```
    print(f"{class_names[i]:>10s}: {prob:.4f}")

predicted_class = np.argmax(result)
print(f"\nClasse prevista: {class_names[predicted_class]}␣
 ↪({result[0][predicted_class]:.4f})")
```


```
/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/data/ops/structured_function.py:258: UserWarning:
Even though the `tf.config.experimental_run_functions_eagerly` option is set,
this option does not apply to tf.data functions. To force eager execution of
tf.data functions, please use `tf.data.experimental.enable_debug_mode()`.
  warnings.warn(
1/1             1s 977ms/step
Probabilidades por classe:
 buildings: 0.0000
    forest: 0.0000
   glacier: 0.0000
  mountain: 0.0000
       sea: 1.0000
    street: 0.0000

Classe prevista: sea (1.0000)
```

4.7 Comparação dos modelos utilizando a accuracy

[13]:
```
val_loss, val_acc = full_model.evaluate(validation_dataset)
val_loss_t_DA, val_acc_DA = model_DA.evaluate(validation_dataset)


print("Validation Accuracy dos modelos:")
print(f"Model feature extraction: {val_acc:.4f}")
print(f"Model feature extraction + Data augmentation: {val_acc_DA:.4f}")


results = {
    'Without data augmentation': val_acc,
    'With data augmentation': val_acc_DA,
}

# Identificar o melhor modelo com base na maior val_accuracy
best_model = max(results, key=results.get)
best_accuracy = results[best_model]

print(f"\nMelhor modelo: {best_model} com val_accuracy = {best_accuracy:.4f}")
```

```
94/94             7s 70ms/step -
accuracy: 0.9155 - loss: 1.2081
94/94             6s 63ms/step -
accuracy: 0.9121 - loss: 0.5651
Validation Accuracy dos modelos:
Model feature extraction: 0.9187
Model feature extraction + Data augmentation: 0.9063

Melhor modelo: Without data augmentation com val_accuracy = 0.9187
```

4.8 Calcular saída do modelo para uma imagem

[20]:
```
img_path = 'Dataset/archive/seg_test/sea/20072.jpg'

img = tf.keras.preprocessing.image.load_img(
    img_path,
    target_size=(150, 150),
    interpolation='bilinear'
)

plt.imshow(img)
plt.axis('off')
plt.title("Imagem de Teste")
plt.show()

img_array = tf.keras.preprocessing.image.img_to_array(img)
```

```
img_array = tf.expand_dims(img_array, 0)

result = model_DA.predict(img_array)

class_names = ['buildings', 'forest', 'glacier', 'mountain', 'sea', 'street']
print("Probabilidades por classe:")
for i, prob in enumerate(result[0]):
    print(f"{class_names[i]:>10s}: {prob:.4f}")


predicted_class = np.argmax(result)
print(f"\nClasse prevista: {class_names[predicted_class]}␣
 ↪({result[0][predicted_class]:.4f})")
```


```
1/1             1s 1s/step
Probabilidades por classe:
 buildings: 0.0000
    forest: 0.0000
   glacier: 0.0000
  mountain: 0.0000
       sea: 1.0000
    street: 0.0000
```

```
Classe prevista: sea (1.0000)
```