modelT_fineTuning

June 12, 2025

[7]:
```
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
from sklearn.metrics import classification_report
import os, shutil
```

1 Funções

[ ]:
```
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)
```

1.1 Carregamento do dataset

Carrega o dataset distribuido pelos diferentes conjuntos de dados.

[5]:
```
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**

2 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']
```

3 Carregamento dos modelos

[3]:
```
model = keras.models.load_model('modelT_featureExtraction_full.keras')
model_DA = keras.models.load_model('modelT_featureExtraction_DataAugmentation.
↪keras')
```

```
I0000 00:00:1749766841.810864    1300 gpu_device.cc:2019] Created device
/job:localhost/replica:0/task:0/device:GPU:0 with 6406 MB memory:  -> device: 0,
name: NVIDIA GeForce GTX 1070, pci bus id: 0000:01:00.0, compute capability: 6.1
/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))
```

4 Freeze conv base (model without data augmentation)

Ativação do treino do modelo VGG16 pré-treinado (convbase) e congelamento de todas as camadas exceto as últimas quatro, permitindo ajustar apenas as camadas superiores durante o fine-tuning. Imprissão do estado de cada camada para confirmar quais estão treináveis.

[5]:
```
convbase = model.get_layer("vgg16")
convbase.trainable = True
```

```
for layer in convbase.layers[:-4]:
    layer.trainable = False
for i, layer in enumerate(convbase.layers):
    print(i, layer.name, layer.trainable)
```

```
0 input_layer False
1 block1_conv1 False
2 block1_conv2 False
3 block1_pool False
4 block2_conv1 False
5 block2_conv2 False
6 block2_pool False
7 block3_conv1 False
8 block3_conv2 False
9 block3_conv3 False
10 block3_pool False
11 block4_conv1 False
12 block4_conv2 False
13 block4_conv3 False
14 block4_pool False
15 block5_conv1 True
16 block5_conv2 True
17 block5_conv3 True
18 block5_pool True
```

4.1 Compilação da CNN

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

[6]:
```
model.compile(optimizer=tf.keras.optimizers.RMSprop(learning_rate=1e-4),␣
↪loss='categorical_crossentropy', metrics=['accuracy'])
```

4.2 Definição do callback

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

[7]:
```
checkpoint_filepath = 'modelT_fineTuning.keras'
model_checkpoint_callback = keras.callbacks.ModelCheckpoint(
    filepath=checkpoint_filepath,
    monitor='val_loss',
    save_best_only=True)
```

4.3 Treino da CNN

Treino da CNN durante 50 épocas utilizando o dataset de validação e o callback para guardar o melhor modelo.

[8]:
```
history = model.fit(
train_dataset,
epochs=50,
validation_data=validation_dataset,
callbacks=[model_checkpoint_callback])
```

```
Epoch 1/50
```

```
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
I0000 00:00:1749675373.235249  103471 service.cc:152] XLA service 0x7d2dd80042b0
initialized for platform CUDA (this does not guarantee that XLA will be used).
Devices:
I0000 00:00:1749675373.235292  103471 service.cc:160]   StreamExecutor device
(0): NVIDIA GeForce GTX 1070, Compute Capability 6.1
2025-06-11 21:56:13.352846: 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 00:00:1749675373.750440  103471 cuda_dnn.cc:529] Loaded cuDNN version
90300
2025-06-11 21:56:18.065368: 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.4472, f32[64,3,3,3]{3,2,1,0}
%bitcast.4479, f32[64]{0} %bitcast.4481), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:56:18.422745: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.40 = (f32[32,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,64,150,150]{3,2,1,0} %bitcast.4486, f32[64,64,3,3]{3,2,1,0}
%bitcast.4493, f32[64]{0} %bitcast.4495), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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 21:56:19.885281: 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.4503, f32[128,64,3,3]{3,2,1,0}
%bitcast.4510, f32[128]{0} %bitcast.4512), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:56:20.712831: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.42 = (f32[32,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,128,75,75]{3,2,1,0} %bitcast.4517, f32[128,128,3,3]{3,2,1,0}
%bitcast.4524, f32[128]{0} %bitcast.4526), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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 21:56:21.610686: 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.4532, f32[256,128,3,3]{3,2,1,0}
%bitcast.4539, f32[256]{0} %bitcast.4541), 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 21:56:22.134464: 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.4546, f32[256,256,3,3]{3,2,1,0}
%bitcast.4553, f32[256]{0} %bitcast.4555), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block3_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:56:23.266203: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.46 = (f32[32,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,256,18,18]{3,2,1,0} %bitcast.4575, f32[512,256,3,3]{3,2,1,0}
%bitcast.4582, f32[512]{0} %bitcast.4584), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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 21:56:23.852662: 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.4589, f32[512,512,3,3]{3,2,1,0}
%bitcast.4596, f32[512]{0} %bitcast.4598), 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 21:56:24.886994: 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.4808, f32[512,512,3,3]{3,2,1,0}
%bitcast.4625, f32[512]{0} %bitcast.4991), 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":"kNone","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}

  2/345            32s 95ms/step - accuracy:
1.0000 - loss: 6.2721e-06

I0000 00:00:1749675387.517783  103471 device_compiler.h:188] Compiled cluster
using XLA!  This line is logged at most once for the lifetime of the process.

344/345            0s 100ms/step -
accuracy: 0.8881 - loss: 0.5894

2025-06-11 21:57:02.917473: 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.4472, f32[64,3,3,3]{3,2,1,0}
%bitcast.4479, f32[64]{0} %bitcast.4481), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:03.211909: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.40 = (f32[26,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,64,150,150]{3,2,1,0} %bitcast.4486, f32[64,64,3,3]{3,2,1,0}
%bitcast.4493, f32[64]{0} %bitcast.4495), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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 21:57:04.477480: 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.4503, f32[128,64,3,3]{3,2,1,0}
%bitcast.4510, f32[128]{0} %bitcast.4512), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:05.088668: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.42 = (f32[26,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[26,128,75,75]{3,2,1,0} %bitcast.4517, f32[128,128,3,3]{3,2,1,0}
%bitcast.4524, f32[128]{0} %bitcast.4526), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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 21:57:05.830088: 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.4532, f32[256,128,3,3]{3,2,1,0}
%bitcast.4539, f32[256]{0} %bitcast.4541), 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 21:57:06.729355: 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.4546, f32[256,256,3,3]{3,2,1,0} %bitcast.4553, f32[256]{0} %bitcast.4555), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type="Conv2D" op_name="functional_1_1/vgg16_1/block3_conv2_1/convolution" source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:07.474188: I external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-activation.46 = (f32[26,512,18,18]{3,2,1,0}, u8[0]{0}) custom-call(f32[26,256,18,18]{3,2,1,0} %bitcast.4575, f32[512,256,3,3]{3,2,1,0} %bitcast.4582, f32[512]{0} %bitcast.4584), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01, custom_call_target="__cudnn$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_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:07.842994: 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.4589, f32[512,512,3,3]{3,2,1,0} %bitcast.4596, f32[512]{0} %bitcast.4598), 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_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:08.485793: 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.4808, f32[512,512,3,3]{3,2,1,0}

%bitcast.4625, f32[512]{0} %bitcast.4991), 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"
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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":"kNone","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}

345/345 0s 125ms/step -
accuracy: 0.8880 - loss: 0.5893

2025-06-11 21:57:13.914849: 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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block5_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
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g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:21.231153: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.39 = (f32[24,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,3,150,150]{3,2,1,0} %bitcast.850, f32[64,3,3,3]{3,2,1,0}
%bitcast.857, f32[64]{0} %bitcast.859), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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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g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:21.471753: 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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:22.829216: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.41 = (f32[24,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,64,75,75]{3,2,1,0} %bitcast.881, f32[128,64,3,3]{3,2,1,0}
%bitcast.888, f32[128]{0} %bitcast.890), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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}
2025-06-11 21:57:23.469580: 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,
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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}
2025-06-11 21:57:24.203705: 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"
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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
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:24.728044: 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}
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dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block3_conv2_1/convolution"
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packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:25.457713: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.46 = (f32[24,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
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%bitcast.960, f32[512]{0} %bitcast.962), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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={
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:25.833495: 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$convBiasActivationForward",
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op_name="functional_1_1/vgg16_1/block4_conv2_1/convolution"
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packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
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elu_alpha":0},"force_earliest_schedule":false}
2025-06-11 21:57:26.547449: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.49 = (f32[24,512,9,9]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,512,9,9]{3,2,1,0} %bitcast.996, f32[512,512,3,3]{3,2,1,0}
%bitcast.1003, f32[512]{0} %bitcast.1005), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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={
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g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}

345/345 **77s** 178ms/step -
accuracy: 0.8880 - loss: 0.5891 - val_accuracy: 0.8570 - val_loss: 0.5139
Epoch 2/50
345/345 **43s** 123ms/step -
accuracy: 0.8778 - loss: 0.4332 - val_accuracy: 0.8850 - val_loss: 0.4489
Epoch 3/50
345/345 **42s** 122ms/step -
accuracy: 0.8992 - loss: 0.3849 - val_accuracy: 0.8900 - val_loss: 0.5676
Epoch 4/50
345/345 **45s** 130ms/step -
accuracy: 0.9108 - loss: 0.3207 - val_accuracy: 0.8777 - val_loss: 0.3595
Epoch 5/50
345/345 **41s** 118ms/step -
accuracy: 0.9117 - loss: 0.3213 - val_accuracy: 0.8853 - val_loss: 0.3997
Epoch 6/50
345/345 **41s** 120ms/step -
accuracy: 0.9115 - loss: 0.3102 - val_accuracy: 0.9150 - val_loss: 0.4201
Epoch 7/50
345/345 **42s** 120ms/step -
accuracy: 0.9224 - loss: 0.3011 - val_accuracy: 0.9140 - val_loss: 0.6218
Epoch 8/50
345/345 **41s** 120ms/step -
accuracy: 0.9284 - loss: 0.3122 - val_accuracy: 0.8993 - val_loss: 0.4610
Epoch 9/50
345/345 **44s** 129ms/step -
accuracy: 0.9275 - loss: 0.2707 - val_accuracy: 0.8983 - val_loss: 0.5548
Epoch 10/50
345/345 **42s** 120ms/step -

```
accuracy: 0.9345 - loss: 0.2685 - val_accuracy: 0.8873 - val_loss: 0.6249
Epoch 11/50
345/345             42s 120ms/step -
accuracy: 0.9381 - loss: 0.2650 - val_accuracy: 0.8887 - val_loss: 0.8209
Epoch 12/50
345/345             42s 120ms/step -
accuracy: 0.9334 - loss: 0.2680 - val_accuracy: 0.9037 - val_loss: 1.1006
Epoch 13/50
345/345             41s 120ms/step -
accuracy: 0.9399 - loss: 0.2924 - val_accuracy: 0.9020 - val_loss: 0.8329
Epoch 14/50
345/345             44s 129ms/step -
accuracy: 0.9450 - loss: 0.3028 - val_accuracy: 0.8633 - val_loss: 1.0001
Epoch 15/50
345/345             42s 120ms/step -
accuracy: 0.9373 - loss: 0.3703 - val_accuracy: 0.8970 - val_loss: 1.8747
Epoch 16/50
345/345             42s 120ms/step -
accuracy: 0.9349 - loss: 0.4709 - val_accuracy: 0.9113 - val_loss: 1.3725
Epoch 17/50
345/345             41s 120ms/step -
accuracy: 0.9471 - loss: 0.2274 - val_accuracy: 0.8830 - val_loss: 1.2662
Epoch 18/50
345/345             41s 120ms/step -
accuracy: 0.9477 - loss: 0.2558 - val_accuracy: 0.9057 - val_loss: 2.5629
Epoch 19/50
345/345             44s 129ms/step -
accuracy: 0.9503 - loss: 0.3471 - val_accuracy: 0.8627 - val_loss: 5.0425
Epoch 20/50
345/345             42s 120ms/step -
accuracy: 0.9431 - loss: 0.3188 - val_accuracy: 0.8447 - val_loss: 5.1792
Epoch 21/50
345/345             41s 120ms/step -
accuracy: 0.9511 - loss: 0.3328 - val_accuracy: 0.9047 - val_loss: 3.8637
Epoch 22/50
345/345             41s 120ms/step -
accuracy: 0.9460 - loss: 0.3171 - val_accuracy: 0.8990 - val_loss: 4.6865
Epoch 23/50
345/345             41s 120ms/step -
accuracy: 0.9471 - loss: 0.3710 - val_accuracy: 0.8863 - val_loss: 0.9242
Epoch 24/50
345/345             44s 129ms/step -
accuracy: 0.9434 - loss: 0.3362 - val_accuracy: 0.8947 - val_loss: 2.7369
Epoch 25/50
345/345             41s 120ms/step -
accuracy: 0.9468 - loss: 0.3651 - val_accuracy: 0.8960 - val_loss: 3.2636
Epoch 26/50
345/345             41s 120ms/step -
```

```
accuracy: 0.9468 - loss: 0.4730 - val_accuracy: 0.9090 - val_loss: 1.6757
Epoch 27/50
345/345             41s 120ms/step -
accuracy: 0.9436 - loss: 0.3871 - val_accuracy: 0.8667 - val_loss: 3.5337
Epoch 28/50
345/345             42s 120ms/step -
accuracy: 0.9376 - loss: 0.3366 - val_accuracy: 0.8840 - val_loss: 1.4945
Epoch 29/50
345/345             41s 120ms/step -
accuracy: 0.9498 - loss: 0.4342 - val_accuracy: 0.8857 - val_loss: 1.9144
Epoch 30/50
345/345             43s 124ms/step -
accuracy: 0.9491 - loss: 0.3255 - val_accuracy: 0.8827 - val_loss: 3.1259
Epoch 31/50
345/345             40s 115ms/step -
accuracy: 0.9503 - loss: 0.5267 - val_accuracy: 0.8990 - val_loss: 3.2385
Epoch 32/50
345/345             40s 115ms/step -
accuracy: 0.9583 - loss: 0.2566 - val_accuracy: 0.9000 - val_loss: 2.3703
Epoch 33/50
345/345             40s 115ms/step -
accuracy: 0.9407 - loss: 0.4618 - val_accuracy: 0.9000 - val_loss: 4.3635
Epoch 34/50
345/345             40s 115ms/step -
accuracy: 0.9534 - loss: 0.5483 - val_accuracy: 0.9117 - val_loss: 3.1143
Epoch 35/50
345/345             40s 115ms/step -
accuracy: 0.9484 - loss: 0.3827 - val_accuracy: 0.8870 - val_loss: 2.9856
Epoch 36/50
345/345             40s 115ms/step -
accuracy: 0.9481 - loss: 0.3315 - val_accuracy: 0.8883 - val_loss: 1.2460
Epoch 37/50
345/345             43s 124ms/step -
accuracy: 0.9503 - loss: 0.4693 - val_accuracy: 0.9023 - val_loss: 3.9409
Epoch 38/50
345/345             40s 115ms/step -
accuracy: 0.9477 - loss: 0.5065 - val_accuracy: 0.9020 - val_loss: 4.0016
Epoch 39/50
345/345             40s 115ms/step -
accuracy: 0.9472 - loss: 0.3046 - val_accuracy: 0.9120 - val_loss: 5.1110
Epoch 40/50
345/345             40s 115ms/step -
accuracy: 0.9448 - loss: 0.5555 - val_accuracy: 0.8920 - val_loss: 3.8418
Epoch 41/50
345/345             40s 115ms/step -
accuracy: 0.9531 - loss: 0.6895 - val_accuracy: 0.8857 - val_loss: 8.2561
Epoch 42/50
345/345             40s 115ms/step -
```

```
accuracy: 0.9460 - loss: 0.4003 - val_accuracy: 0.9007 - val_loss: 2.9004
Epoch 43/50
345/345             40s 115ms/step -
accuracy: 0.9526 - loss: 0.3755 - val_accuracy: 0.8983 - val_loss: 4.2611
Epoch 44/50
345/345             43s 124ms/step -
accuracy: 0.9596 - loss: 0.4265 - val_accuracy: 0.8993 - val_loss: 6.5087
Epoch 45/50
345/345             40s 115ms/step -
accuracy: 0.9563 - loss: 0.4090 - val_accuracy: 0.8770 - val_loss: 3.9923
Epoch 46/50
345/345             40s 115ms/step -
accuracy: 0.9379 - loss: 0.5649 - val_accuracy: 0.8920 - val_loss: 3.0582
Epoch 47/50
345/345             40s 115ms/step -
accuracy: 0.9581 - loss: 0.6871 - val_accuracy: 0.8993 - val_loss: 6.9974
Epoch 48/50
345/345             40s 115ms/step -
accuracy: 0.9618 - loss: 0.4716 - val_accuracy: 0.8957 - val_loss: 5.0655
Epoch 49/50
345/345             40s 115ms/step -
accuracy: 0.9387 - loss: 0.6017 - val_accuracy: 0.9003 - val_loss: 7.4141
Epoch 50/50
345/345             40s 115ms/step -
accuracy: 0.9443 - loss: 0.4698 - val_accuracy: 0.8967 - val_loss: 6.4359
```

4.4 Carregamento do modelo e validação

Carregamento e avaliação do modelo através do valor da accuracy.

[8]:
```python
# Loading and testing the model
model = keras.models.load_model('modelT_fineTuning.keras')
val_loss, val_acc = model.evaluate(validation_dataset)
print('val_acc:', val_acc)
```

```
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
I0000 00:00:1749766911.495682    1673 service.cc:152] XLA service 0x719dd400d0a0
initialized for platform CUDA (this does not guarantee that XLA will be used).
Devices:
I0000 00:00:1749766911.495732    1673 service.cc:160]   StreamExecutor device
(0): NVIDIA GeForce GTX 1070, Compute Capability 6.1
2025-06-12 23:21:51.540207: 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 00:00:1749766911.648313    1673 cuda_dnn.cc:529] Loaded cuDNN version
90300
2025-06-12 23:21:54.656154: 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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:21:54.965463: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.40 = (f32[32,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,64,150,150]{3,2,1,0} %bitcast.864, f32[64,64,3,3]{3,2,1,0}
%bitcast.871, f32[64]{0} %bitcast.873), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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 23:21:56.125571: 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={
"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 23:21:56.827401: 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.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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:21:57.682018: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.43 = (f32[32,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,128,37,37]{3,2,1,0} %bitcast.910, f32[256,128,3,3]{3,2,1,0}
%bitcast.917, f32[256]{0} %bitcast.919), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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 23:21:58.136333: 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.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 23:21:59.004185: 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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:21:59.460687: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.47 = (f32[32,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,512,18,18]{3,2,1,0} %bitcast.967, f32[512,512,3,3]{3,2,1,0}
%bitcast.974, f32[512]{0} %bitcast.976), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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 23:22:00.311674: 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",
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}

 2/94            6s 75ms/step - accuracy:
0.8516 - loss: 0.3470

I0000 00:00:1749766921.174882    1673 device_compiler.h:188] Compiled cluster
using XLA!  This line is logged at most once for the lifetime of the process.

93/94            0s 102ms/step -
accuracy: 0.8806 - loss: 0.3262

2025-06-12 23:22:11.066727: 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$convBiasActivationForward", metadata={op_type="Conv2D" op_name="functional_1_1/vgg16_1/block1_conv1_1/convolution" source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:22:11.372799: I external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-activation.40 = (f32[24,64,150,150]{3,2,1,0}, u8[0]{0}) custom-call(f32[24,64,150,150]{3,2,1,0} %bitcast.864, f32[64,64,3,3]{3,2,1,0} %bitcast.871, f32[64]{0} %bitcast.873), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type="Conv2D" op_name="functional_1_1/vgg16_1/block1_conv2_1/convolution" 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}
2025-06-12 23:22:12.253627: 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_config":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:22:12.818080: 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}

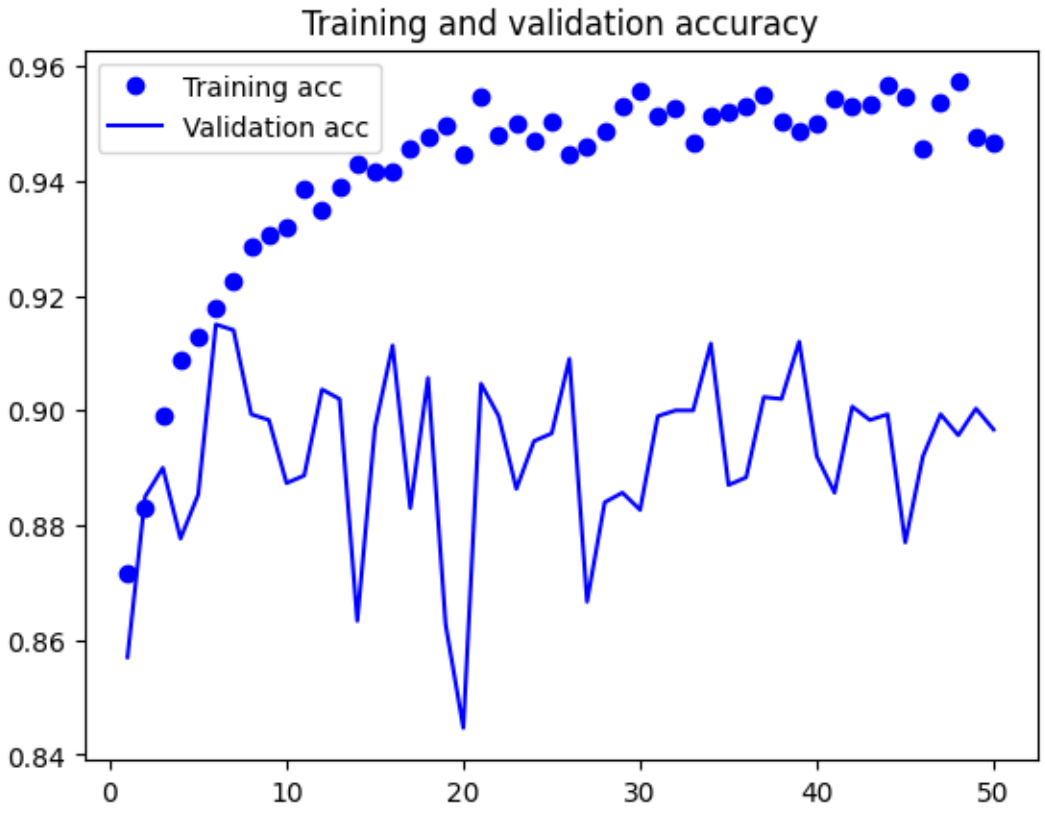
%bitcast.902, f32[128]{0} %bitcast.904), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block2_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:22:13.460224: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.43 = (f32[24,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,128,37,37]{3,2,1,0} %bitcast.910, f32[256,128,3,3]{3,2,1,0}
%bitcast.917, f32[256]{0} %bitcast.919), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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 23:22:13.843874: 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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block3_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:22:14.553661: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.46 = (f32[24,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,256,18,18]{3,2,1,0} %bitcast.953, f32[512,256,3,3]{3,2,1,0}
%bitcast.960, f32[512]{0} %bitcast.962), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$convBiasActivationForward",

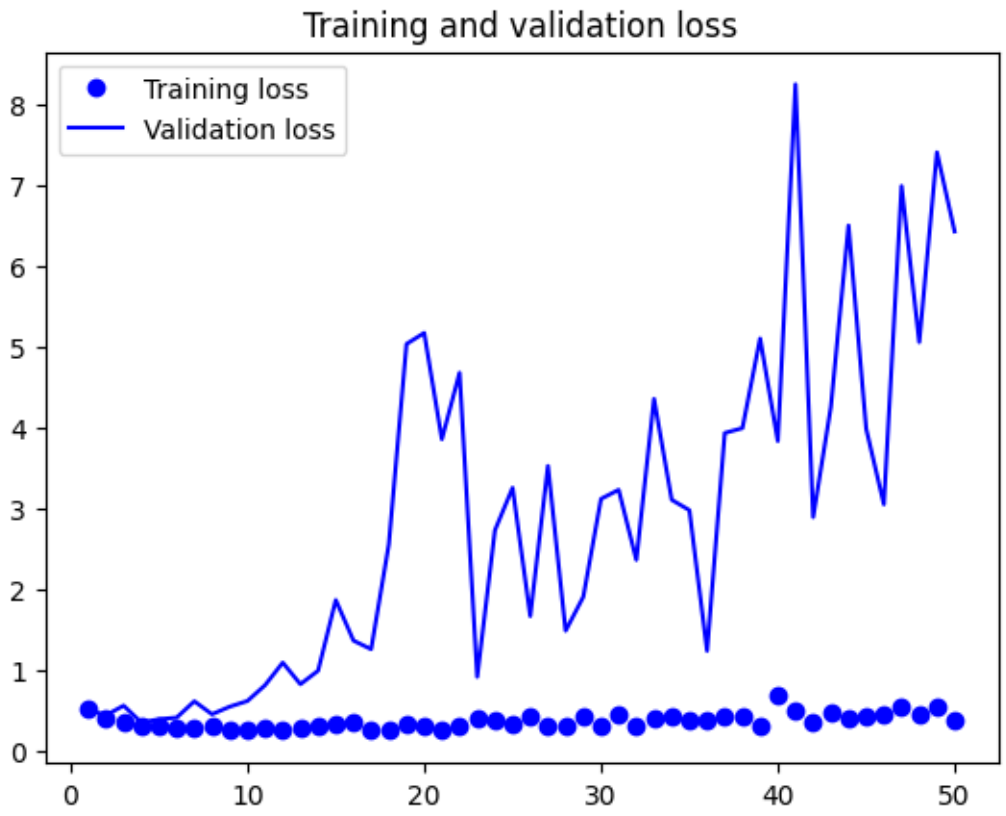
```
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:22:14.933856: 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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:22:15.583097: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.49 = (f32[24,512,9,9]{3,2,1,0}, u8[0]{0}) custom-
call(f32[24,512,9,9]{3,2,1,0} %bitcast.996, f32[512,512,3,3]{3,2,1,0}
%bitcast.1003, f32[512]{0} %bitcast.1005), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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            26s 162ms/step -
accuracy: 0.8805 - loss: 0.3269
val_acc: 0.8776666522026062
```

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

[12]:
```
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()
```





5 Freeze conv base (model with data augmentation)

[13]:
```
convbase_DA = model_DA.get_layer("vgg16")
convbase_DA.trainable = True
for layer in convbase_DA.layers[:-4]:
    layer.trainable = False
for i, layer in enumerate(convbase_DA.layers):
    print(i, layer.name, layer.trainable)
```

```
0 input_layer_3 False
1 block1_conv1 False
2 block1_conv2 False
3 block1_pool False
4 block2_conv1 False
5 block2_conv2 False
6 block2_pool False
7 block3_conv1 False
8 block3_conv2 False
9 block3_conv3 False
10 block3_pool False
```

```
11 block4_conv1 False
12 block4_conv2 False
13 block4_conv3 False
14 block4_pool False
15 block5_conv1 True
16 block5_conv2 True
17 block5_conv3 True
18 block5_pool True
```

5.1 Compilação da CNN

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

[14]:
```
model_DA.compile(optimizer=tf.keras.optimizers.RMSprop(learning_rate=1e-4),␣
↪loss='categorical_crossentropy', metrics=['accuracy'])
```

5.2 Definição do callback

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

[15]:
```
checkpoint_filepath_DA = 'modelT_fineTuning_DataAugmentation.keras'
model_checkpoint_callback_DA = keras.callbacks.ModelCheckpoint(
    filepath=checkpoint_filepath_DA,
    monitor='val_loss',
    save_best_only=True)
```

5.3 Treino da CNN

Treino da CNN durante 50 épocas utilizando o dataset de validação e o callback para guardar o melhor modelo.

[16]:
```
history_DA = model_DA.fit(
train_dataset,
epochs=50,
validation_data=validation_dataset,
callbacks=[model_checkpoint_callback_DA])
```

```
Epoch 1/50
345/345             46s 119ms/step -
accuracy: 0.8146 - loss: 0.6256 - val_accuracy: 0.9023 - val_loss: 0.3703
Epoch 2/50
345/345             36s 105ms/step -
accuracy: 0.8563 - loss: 0.4852 - val_accuracy: 0.8760 - val_loss: 0.6289
Epoch 3/50
345/345             36s 106ms/step -
accuracy: 0.8678 - loss: 0.4349 - val_accuracy: 0.9083 - val_loss: 0.5470
Epoch 4/50
345/345             37s 108ms/step -
```

```
accuracy: 0.8750 - loss: 0.4388 - val_accuracy: 0.9067 - val_loss: 0.3656
Epoch 5/50
345/345             56s 162ms/step -
accuracy: 0.8797 - loss: 0.3924 - val_accuracy: 0.8883 - val_loss: 0.5498
Epoch 6/50
345/345             130s 375ms/step -
accuracy: 0.8829 - loss: 0.4157 - val_accuracy: 0.9047 - val_loss: 0.3831
Epoch 7/50
345/345             129s 374ms/step -
accuracy: 0.8840 - loss: 0.3831 - val_accuracy: 0.9067 - val_loss: 0.4357
Epoch 8/50
345/345             133s 386ms/step -
accuracy: 0.8874 - loss: 0.3989 - val_accuracy: 0.8820 - val_loss: 0.4309
Epoch 9/50
345/345             137s 397ms/step -
accuracy: 0.8805 - loss: 0.4036 - val_accuracy: 0.9137 - val_loss: 0.4523
Epoch 10/50
345/345             123s 355ms/step -
accuracy: 0.8826 - loss: 0.4370 - val_accuracy: 0.8977 - val_loss: 0.6730
Epoch 11/50
345/345             134s 388ms/step -
accuracy: 0.8829 - loss: 0.4578 - val_accuracy: 0.9090 - val_loss: 0.5982
Epoch 12/50
345/345             131s 378ms/step -
accuracy: 0.8876 - loss: 0.4364 - val_accuracy: 0.9113 - val_loss: 0.6406
Epoch 13/50
345/345             134s 389ms/step -
accuracy: 0.8931 - loss: 0.4061 - val_accuracy: 0.8567 - val_loss: 1.3012
Epoch 14/50
345/345             131s 380ms/step -
accuracy: 0.8817 - loss: 0.4657 - val_accuracy: 0.9160 - val_loss: 0.6448
Epoch 15/50
345/345             131s 379ms/step -
accuracy: 0.8897 - loss: 0.4082 - val_accuracy: 0.8783 - val_loss: 0.7162
Epoch 16/50
345/345             130s 377ms/step -
accuracy: 0.8880 - loss: 0.4309 - val_accuracy: 0.8883 - val_loss: 0.4755
Epoch 17/50
345/345             134s 388ms/step -
accuracy: 0.8850 - loss: 0.4128 - val_accuracy: 0.8617 - val_loss: 0.4589
Epoch 18/50
345/345             131s 381ms/step -
accuracy: 0.8834 - loss: 0.4260 - val_accuracy: 0.9007 - val_loss: 0.4936
Epoch 19/50
345/345             134s 389ms/step -
accuracy: 0.8975 - loss: 0.3880 - val_accuracy: 0.9067 - val_loss: 0.4350
Epoch 20/50
345/345             136s 395ms/step -
```

```
accuracy: 0.8879 - loss: 0.4324 - val_accuracy: 0.8877 - val_loss: 0.6956
Epoch 21/50
345/345             138s 399ms/step -
accuracy: 0.8811 - loss: 0.4187 - val_accuracy: 0.8917 - val_loss: 1.9789
Epoch 22/50
345/345             132s 382ms/step -
accuracy: 0.8734 - loss: 0.5397 - val_accuracy: 0.8560 - val_loss: 1.6675
Epoch 23/50
345/345             127s 368ms/step -
accuracy: 0.8816 - loss: 0.4986 - val_accuracy: 0.8940 - val_loss: 0.6806
Epoch 24/50
345/345             69s 198ms/step -
accuracy: 0.8824 - loss: 0.5028 - val_accuracy: 0.9063 - val_loss: 0.8059
Epoch 25/50
345/345             37s 106ms/step -
accuracy: 0.8791 - loss: 0.5331 - val_accuracy: 0.8867 - val_loss: 0.6732
Epoch 26/50
345/345             37s 106ms/step -
accuracy: 0.8752 - loss: 0.4706 - val_accuracy: 0.9060 - val_loss: 0.8924
Epoch 27/50
345/345             37s 107ms/step -
accuracy: 0.8784 - loss: 0.5083 - val_accuracy: 0.8717 - val_loss: 1.9143
Epoch 28/50
345/345             37s 107ms/step -
accuracy: 0.8709 - loss: 0.4814 - val_accuracy: 0.8897 - val_loss: 1.0503
Epoch 29/50
345/345             40s 115ms/step -
accuracy: 0.8611 - loss: 0.5632 - val_accuracy: 0.8733 - val_loss: 0.9605
Epoch 30/50
345/345             37s 107ms/step -
accuracy: 0.8563 - loss: 0.6818 - val_accuracy: 0.8673 - val_loss: 0.9034
Epoch 31/50
345/345             37s 107ms/step -
accuracy: 0.8510 - loss: 0.6722 - val_accuracy: 0.8820 - val_loss: 0.7016
Epoch 32/50
345/345             37s 107ms/step -
accuracy: 0.8611 - loss: 0.6043 - val_accuracy: 0.8873 - val_loss: 1.5366
Epoch 33/50
345/345             37s 107ms/step -
accuracy: 0.8505 - loss: 0.6816 - val_accuracy: 0.9013 - val_loss: 1.1480
Epoch 34/50
345/345             37s 107ms/step -
accuracy: 0.8437 - loss: 0.6969 - val_accuracy: 0.8900 - val_loss: 2.2903
Epoch 35/50
345/345             37s 107ms/step -
accuracy: 0.8526 - loss: 0.6846 - val_accuracy: 0.9063 - val_loss: 1.1871
Epoch 36/50
345/345             37s 107ms/step -
```

```
accuracy: 0.8551 - loss: 0.6596 - val_accuracy: 0.8723 - val_loss: 2.0882
Epoch 37/50
345/345             37s 107ms/step -
accuracy: 0.8478 - loss: 0.6864 - val_accuracy: 0.8760 - val_loss: 1.5875
Epoch 38/50
345/345             37s 107ms/step -
accuracy: 0.8380 - loss: 0.7850 - val_accuracy: 0.8873 - val_loss: 1.7841
Epoch 39/50
345/345             37s 107ms/step -
accuracy: 0.8389 - loss: 0.7858 - val_accuracy: 0.8837 - val_loss: 1.5491
Epoch 40/50
345/345             37s 107ms/step -
accuracy: 0.8524 - loss: 0.6526 - val_accuracy: 0.8777 - val_loss: 3.7493
Epoch 41/50
345/345             37s 107ms/step -
accuracy: 0.8521 - loss: 0.7032 - val_accuracy: 0.8227 - val_loss: 2.7415
Epoch 42/50
345/345             37s 107ms/step -
accuracy: 0.8311 - loss: 0.8237 - val_accuracy: 0.8753 - val_loss: 1.0985
Epoch 43/50
345/345             37s 108ms/step -
accuracy: 0.8280 - loss: 0.7735 - val_accuracy: 0.8770 - val_loss: 0.7090
Epoch 44/50
345/345             37s 107ms/step -
accuracy: 0.8171 - loss: 1.1750 - val_accuracy: 0.8643 - val_loss: 2.2038
Epoch 45/50
345/345             37s 107ms/step -
accuracy: 0.8106 - loss: 0.8290 - val_accuracy: 0.8840 - val_loss: 1.1357
Epoch 46/50
345/345             37s 107ms/step -
accuracy: 0.8044 - loss: 1.0274 - val_accuracy: 0.8567 - val_loss: 6.3765
Epoch 47/50
345/345             40s 116ms/step -
accuracy: 0.8190 - loss: 0.9580 - val_accuracy: 0.8797 - val_loss: 3.8975
Epoch 48/50
345/345             37s 107ms/step -
accuracy: 0.8203 - loss: 1.1227 - val_accuracy: 0.8717 - val_loss: 1.7223
Epoch 49/50
345/345             37s 107ms/step -
accuracy: 0.8099 - loss: 1.0078 - val_accuracy: 0.8697 - val_loss: 1.3123
Epoch 50/50
345/345             37s 107ms/step -
accuracy: 0.8062 - loss: 0.9541 - val_accuracy: 0.8777 - val_loss: 1.9295
```

5.4 Carregamento do modelo e validação

Carregamento e avaliação do modelo através do valor da accuracy.

[9]:
```
model_DA = keras.models.load_model('modelT_fineTuning_DataAugmentation.keras')
val_loss, val_acc = model_DA.evaluate(validation_dataset)
print('val_acc:', val_acc)
```

```
94/94            13s 112ms/step -
accuracy: 0.9042 - loss: 0.3575
val_acc: 0.9066666960716248
```

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

[ ]:
```
acc = history_DA.history['acc']
val_acc = history_DA.history['val_acc']
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()
```

Avaliação da performance do modelo no conjunto de teste, utilizando o relatório de classificação. O relatório apresenta, para cada classe, as métricas precision, recall e F1-score, permitindo analisar detalhadamente os acertos e erros por classe.

[ ]:
```
y_true, y_pred = get_true_pred(model_DA, test_dataset)
report = classification_report(y_true, y_pred, target_names=class_names,␣
 ↪output_dict=True)
class_only_report = {k: v for k, v in report.items() if k in class_names}
df = pd.DataFrame(class_only_report).T
print(df[['precision', 'recall', 'f1-score']].round(3))
```

5.5 Comparação dos modelos utilizando a accuracy

[10]:
```
val_loss_, val_acc = model.evaluate(validation_dataset)
val_loss_DA, val_acc_CatCross_DA= model_DA.evaluate(validation_dataset)

print("Validation Accuracy dos modelos:")
print(f"Fine tuning: {val_loss_:.4f}")
print(f"Fine tuning + Data augmentation: {val_loss_DA:.4f}")


results = {
```

```
    'FineTuning': val_acc,
    'FineTuning_DataAugmentation': val_loss_DA
}

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: 0.8844 - loss: 0.3204
94/94            7s 68ms/step -
accuracy: 0.9056 - loss: 0.3537
Validation Accuracy dos modelos:
Fine tuning: 0.3595
Fine tuning + Data augmentation: 0.3656

Melhor modelo: FineTuning com val_accuracy = 0.8777
```

5.6 Calcular saída do modelo para uma imagem

[11]:
```
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)

# Previsão
result = 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}")

# Classe prevista
predicted_class = np.argmax(result)
```

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


```
2025-06-12 23:23:29.159383: 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}
2025-06-12 23:23:29.270445: 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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block1_conv2_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:23:29.340459: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.41 = (f32[1,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,64,75,75]{3,2,1,0} %bitcast.573, f32[128,64,3,3]{3,2,1,0}
%bitcast.580, f32[128]{0} %bitcast.582), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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}
2025-06-12 23:23:29.421865: 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}
2025-06-12 23:23:29.477428: 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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block3_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:23:29.545891: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.44 = (f32[1,256,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,256,37,37]{3,2,1,0} %bitcast.616, f32[256,256,3,3]{3,2,1,0}
%bitcast.623, f32[256]{0} %bitcast.625), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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}
2025-06-12 23:23:29.606143: 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$convBiasActivationForward",
metadata={op_type="Conv2D"
op_name="functional_1_1/vgg16_1/block4_conv1_1/convolution"
source_file="/home/diogo/.pyenv/versions/3.10.18/lib/python3.10/site-
packages/tensorflow/python/framework/ops.py" source_line=1200}, backend_config={
"operation_queue_id":"0","wait_on_operation_queues":[],"cudnn_conv_backend_confi
g":{"conv_result_scale":1,"activation_mode":"kRelu","side_input_scale":0,"leakyr
elu_alpha":0},"force_earliest_schedule":false}
2025-06-12 23:23:29.690639: I
external/local_xla/xla/service/gpu/autotuning/conv_algorithm_picker.cc:549]
Omitted potentially buggy algorithm eng14{} for conv %cudnn-conv-bias-
activation.47 = (f32[1,512,18,18]{3,2,1,0}, u8[0]{0}) custom-
call(f32[1,512,18,18]{3,2,1,0} %bitcast.659, f32[512,512,3,3]{3,2,1,0}
%bitcast.666, f32[512]{0} %bitcast.668), window={size=3x3 pad=1_1x1_1},
dim_labels=bf01_oi01->bf01,
custom_call_target="__cudnn$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}
2025-06-12 23:23:29.789575: 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             2s 2s/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)
```