1 Quizz

2 Image classification

```
import os
import shutil
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow.keras import layers
from tensorflow.keras import Model
from tensorflow.keras.optimizers import Adam, RMSprop
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.utils import img_to_array, load_img

import matplotlib.image as mpimg
from keras.callbacks import EarlyStopping, ModelCheckpoint,
ReduceLROnPlateau
import keras
```

Creation des dataset Train et Validation

```
# Catégories à traiter
categories = ['Colonial', 'Modern', 'Prehispanic']
train_dir = 'MexCulture142/images_train'
validation_dir = 'MexCulture142/images_val'

# Créer les répertoires d'entraînement et de validation pour chaque
catégorie
for category in categories:
    # Répertoires d'entraînement
    train_category_dir = os.path.join(train_dir, category)
    os.makedirs(train_category_dir, exist_ok=True)

    # Répertoires de validation
    validation_category_dir = os.path.join(validation_dir, category)
    os.makedirs(validation_category_dir, exist_ok=True)

# Répertoires de classes dans train_dir
train_colonial_dir = os.path.join(train_dir, 'Colonial')
train_modern_dir = os.path.join(train_dir, 'Modern')
train_prehispanic_dir = os.path.join(train_dir, 'Prehispanic')

# Répertoires de classes dans validation_dir
validation_colonial_dir = os.path.join(validation_dir, 'Colonial')
validation_modern_dir = os.path.join(validation_dir, 'Modern')
```

```
validation_prehispanic_dir = os.path.join(validation_dir,
'Prehispanic')

# Fonction pour déplacer les images
def move_images(directory, colonial_dir, modern_dir, prehispanic_dir):
    for filename in os.listdir(directory):
        if filename.endswith('.png') or filename.endswith('.jpg'):
            # Extraire le suffixe (la première partie avant
l'underscore '_')
            suffix = filename.split('_')[0]

            # Déplacer l'image dans le bon répertoire
            if suffix == 'Colonial':
                shutil.move(os.path.join(directory, filename),
os.path.join(colonial_dir, filename))
            elif suffix == 'Modern':
                shutil.move(os.path.join(directory, filename),
os.path.join(modern_dir, filename))
            elif suffix == 'Prehispanic':
                shutil.move(os.path.join(directory, filename),
os.path.join(prehispanic_dir, filename))

# Déplacer les images dans les sous-dossiers appropriés
move_images(train_dir, train_colonial_dir, train_modern_dir,
train_prehispanic_dir)
move_images(validation_dir, validation_colonial_dir,
validation_modern_dir, validation_prehispanic_dir)

# Vérifier le nombre d'images déplacées
print(f"There are {len(os.listdir(train_colonial_dir))} Colonial
images for training.")
print(f"There are {len(os.listdir(train_modern_dir))} Modern images
for training.")
print(f"There are {len(os.listdir(train_prehispanic_dir))} Prehispanic
images for training.\n")

print(f"There are {len(os.listdir(validation_colonial_dir))} Colonial
images for validation.")
print(f"There are {len(os.listdir(validation_modern_dir))} Modern
images for validation.")
print(f"There are {len(os.listdir(validation_prehispanic_dir))}
Prehispanic images for validation.")
```

```
There are 150 Colonial images for training.
There are 34 Modern images for training.
There are 52 Prehispanic images for training.

There are 16 Colonial images for validation.
There are 16 Modern images for validation.
There are 16 Prehispanic images for validation.
```

On peut voir que les classes sont très déséquilibrées, ce qui va mener le réseau de neurones à prédire Modern de façon aléatoire.

```
train_colonial_fnames = os.listdir(train_colonial_dir)
train_modern_fnames = os.listdir(train_modern_dir)
train_prehispanic_fnames = os.listdir(train_prehispanic_dir)

# Paramètres pour l'affichage
ncols = 4  # Nombre de colonnes
nrows = 2  # Nombre de lignes

# Créer la figure pour afficher les images
fig = plt.gcf()
fig.set_size_inches(ncols * 4, nrows * 4)

# Spécifiez le nombre d'images à afficher par classe
num_images_per_class = 4

# Afficher les images de chaque classe
for class_idx, (class_dir, class_fnames, title) in enumerate(zip(
    [train_colonial_dir, train_modern_dir, train_prehispanic_dir],
    [train_colonial_fnames, train_modern_fnames,
train_prehispanic_fnames],
    ['Colonial', 'Modern', 'Prehispanic']
)):
    # Sélectionner les images à afficher
    selected_fnames = class_fnames[:num_images_per_class]

    for i, fname in enumerate(selected_fnames):
        img_path = os.path.join(class_dir, fname)

        # Set up subplot; subplot indices start at 1
        sp = plt.subplot(len(selected_fnames), ncols, class_idx *
num_images_per_class + i + 1)
        sp.axis('Off')  # Ne pas afficher les axes (ou les lignes de
grille)

        img = mpimg.imread(img_path)
        plt.imshow(img)
        sp.set_title(title)  # Ajouter le titre de la classe

plt.show()
```

```
def train_val_generators(TRAINING_DIR, VALIDATION_DIR):

  train_datagen = ImageDataGenerator(rescale=1./255
                                    )

  train_generator =
train_datagen.flow_from_directory(directory=TRAINING_DIR,
                                                      batch_size=32,

class_mode='categorical',

target_size=(224, 224))

  validation_datagen = ImageDataGenerator( rescale = 1.0/255. )

  validation_generator =
validation_datagen.flow_from_directory(directory=VALIDATION_DIR,

batch_size=32,

class_mode='categorical',

target_size=(224, 224))
  return train_generator, validation_generator

train_generator, validation_generator =
train_val_generators(train_dir, validation_dir)
```

```
Found 236 images belonging to 3 classes.
Found 48 images belonging to 3 classes.
```

Création du Réseau de neurone

```python
pre_trained_model = tf.keras.applications.ResNet50(
    include_top=False,
    weights='imagenet',
    input_shape=(224, 224, 3),
    classifier_activation='softmax'
)
for layer in pre_trained_model.layers:
    layer.trainable = False

pre_trained_model.summary()
```

```
Model: "resnet50"

┏━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━┳━━━━━━━━━━━━━━
━━━━━┓
┃ Layer (type)        ┃ Output Shape       ┃    Param # ┃ Connected to
┃
┡━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━╇━━━━━━━━━━━━━━
━━━━━┩
│ input_layer         │ (None, 224, 224,   │          0 │ -
│
│ (InputLayer)        │ 3)                 │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv1_pad           │ (None, 230, 230,   │          0 │
input_layer[0][0] │
│ (ZeroPadding2D)     │ 3)                 │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv1_conv (Conv2D) │ (None, 112, 112,   │      9,472 │ conv1_pad[0]
[0]    │
│                     │ 64)                │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv1_bn            │ (None, 112, 112,   │        256 │ conv1_conv[0]
[0]   │
│ (BatchNormalizatio… │ 64)                │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv1_relu          │ (None, 112, 112,   │          0 │ conv1_bn[0]
[0]     │
│ (Activation)        │ 64)                │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
```

```
──────┤
│ pool1_pad           │ (None, 114, 114,  │           0 │ conv1_relu[0]
[0]  │
│ (ZeroPadding2D)     │ 64)               │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ pool1_pool          │ (None, 56, 56,    │           0 │ pool1_pad[0]
[0]   │
│ (MaxPooling2D)      │ 64)               │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv2_block1_1_conv │ (None, 56, 56,    │       4,160 │ pool1_pool[0]
[0]  │
│ (Conv2D)            │ 64)               │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv2_block1_1_bn   │ (None, 56, 56,    │         256 │
conv2_block1_1_c… │
│ (BatchNormalizatio… │ 64)               │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv2_block1_1_relu │ (None, 56, 56,    │           0 │
conv2_block1_1_b… │
│ (Activation)        │ 64)               │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv2_block1_2_conv │ (None, 56, 56,    │      36,928 │
conv2_block1_1_r… │
│ (Conv2D)            │ 64)               │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv2_block1_2_bn   │ (None, 56, 56,    │         256 │
conv2_block1_2_c… │
│ (BatchNormalizatio… │ 64)               │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv2_block1_2_relu │ (None, 56, 56,    │           0 │
conv2_block1_2_b… │
│ (Activation)        │ 64)               │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
```

```
│ conv2_block1_0_conv │ (None, 56, 56,      │      16,640 │ pool1_pool[0]
[0]  │
│ (Conv2D)            │ 256)                │             │
│
├─────────────────────┼─────────────────────┼─────────────┼──────────────
─────┤
│ conv2_block1_3_conv │ (None, 56, 56,      │      16,640 │
conv2_block1_2_r… │
│ (Conv2D)            │ 256)                │             │
│
├─────────────────────┼─────────────────────┼─────────────┼──────────────
─────┤
│ conv2_block1_0_bn   │ (None, 56, 56,      │       1,024 │
conv2_block1_0_c… │
│ (BatchNormalizatio… │ 256)                │             │
│
├─────────────────────┼─────────────────────┼─────────────┼──────────────
─────┤
│ conv2_block1_3_bn   │ (None, 56, 56,      │       1,024 │
conv2_block1_3_c… │
│ (BatchNormalizatio… │ 256)                │             │
│
├─────────────────────┼─────────────────────┼─────────────┼──────────────
─────┤
│ conv2_block1_add    │ (None, 56, 56,      │           0 │
conv2_block1_0_b… │
│ (Add)               │ 256)                │             │
conv2_block1_3_b… │
├─────────────────────┼─────────────────────┼─────────────┼──────────────
─────┤
│ conv2_block1_out    │ (None, 56, 56,      │           0 │
conv2_block1_add… │
│ (Activation)        │ 256)                │             │
│
├─────────────────────┼─────────────────────┼─────────────┼──────────────
─────┤
│ conv2_block2_1_conv │ (None, 56, 56,      │      16,448 │
conv2_block1_out… │
│ (Conv2D)            │ 64)                 │             │
│
├─────────────────────┼─────────────────────┼─────────────┼──────────────
─────┤
│ conv2_block2_1_bn   │ (None, 56, 56,      │         256 │
conv2_block2_1_c… │
│ (BatchNormalizatio… │ 64)                 │             │
│
├─────────────────────┼─────────────────────┼─────────────┼──────────────
─────┤
│ conv2_block2_1_relu │ (None, 56, 56,      │           0 │
conv2_block2_1_b… │
│ (Activation)        │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block2_2_conv │ (None, 56, 56,    │     36,928 │
conv2_block2_1_r… │
│ (Conv2D)            │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block2_2_bn   │ (None, 56, 56,    │        256 │
conv2_block2_2_c… │
│ (BatchNormalizatio… │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block2_2_relu │ (None, 56, 56,    │          0 │
conv2_block2_2_b… │
│ (Activation)        │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block2_3_conv │ (None, 56, 56,    │     16,640 │
conv2_block2_2_r… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block2_3_bn   │ (None, 56, 56,    │      1,024 │
conv2_block2_3_c… │
│ (BatchNormalizatio… │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block2_add    │ (None, 56, 56,    │          0 │
conv2_block1_out… │
│ (Add)               │ 256)              │            │
conv2_block2_3_b… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block2_out    │ (None, 56, 56,    │          0 │
conv2_block2_add… │
│ (Activation)        │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_1_conv │ (None, 56, 56,    │     16,448 │
conv2_block2_out… │
```

```
│ (Conv2D)            │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_1_bn   │ (None, 56, 56,    │        256 │
conv2_block3_1_c… │
│ (BatchNormalizatio… │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_1_relu │ (None, 56, 56,    │          0 │
conv2_block3_1_b… │
│ (Activation)        │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_2_conv │ (None, 56, 56,    │     36,928 │
conv2_block3_1_r… │
│ (Conv2D)            │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_2_bn   │ (None, 56, 56,    │        256 │
conv2_block3_2_c… │
│ (BatchNormalizatio… │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_2_relu │ (None, 56, 56,    │          0 │
conv2_block3_2_b… │
│ (Activation)        │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_3_conv │ (None, 56, 56,    │     16,640 │
conv2_block3_2_r… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_3_bn   │ (None, 56, 56,    │      1,024 │
conv2_block3_3_c… │
│ (BatchNormalizatio… │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_add    │ (None, 56, 56,    │          0 │
conv2_block2_out… │
│ (Add)               │ 256)              │            │
```

```
conv2_block3_3_b… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2_block3_out    │ (None, 56, 56,    │          0 │
conv2_block3_add… │
│ (Activation)        │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_1_conv │ (None, 28, 28,    │     32,896 │
conv2_block3_out… │
│ (Conv2D)            │ 128)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_1_bn   │ (None, 28, 28,    │        512 │
conv3_block1_1_c… │
│ (BatchNormalizatio… │ 128)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_1_relu │ (None, 28, 28,    │          0 │
conv3_block1_1_b… │
│ (Activation)        │ 128)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_2_conv │ (None, 28, 28,    │    147,584 │
conv3_block1_1_r… │
│ (Conv2D)            │ 128)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_2_bn   │ (None, 28, 28,    │        512 │
conv3_block1_2_c… │
│ (BatchNormalizatio… │ 128)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_2_relu │ (None, 28, 28,    │          0 │
conv3_block1_2_b… │
│ (Activation)        │ 128)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_0_conv │ (None, 28, 28,    │    131,584 │
conv2_block3_out… │
│ (Conv2D)            │ 512)              │            │
│
```

```
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_3_conv │ (None, 28, 28,    │     66,048 │
conv3_block1_2_r… │
│ (Conv2D)            │ 512)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_0_bn   │ (None, 28, 28,    │      2,048 │
conv3_block1_0_c… │
│ (BatchNormalizatio… │ 512)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_3_bn   │ (None, 28, 28,    │      2,048 │
conv3_block1_3_c… │
│ (BatchNormalizatio… │ 512)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_add    │ (None, 28, 28,    │          0 │
conv3_block1_0_b… │
│ (Add)               │ 512)              │            │
conv3_block1_3_b… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block1_out    │ (None, 28, 28,    │          0 │
conv3_block1_add… │
│ (Activation)        │ 512)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block2_1_conv │ (None, 28, 28,    │     65,664 │
conv3_block1_out… │
│ (Conv2D)            │ 128)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block2_1_bn   │ (None, 28, 28,    │        512 │
conv3_block2_1_c… │
│ (BatchNormalizatio… │ 128)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv3_block2_1_relu │ (None, 28, 28,    │          0 │
conv3_block2_1_b… │
│ (Activation)        │ 128)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
```

```
─────┤
│ conv3_block2_2_conv │ (None, 28, 28,     │     147,584 │
conv3_block2_1_r… │
│ (Conv2D)            │ 128)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block2_2_bn   │ (None, 28, 28,     │         512 │
conv3_block2_2_c… │
│ (BatchNormalizatio… │ 128)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block2_2_relu │ (None, 28, 28,     │           0 │
conv3_block2_2_b… │
│ (Activation)        │ 128)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block2_3_conv │ (None, 28, 28,     │      66,048 │
conv3_block2_2_r… │
│ (Conv2D)            │ 512)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block2_3_bn   │ (None, 28, 28,     │       2,048 │
conv3_block2_3_c… │
│ (BatchNormalizatio… │ 512)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block2_add    │ (None, 28, 28,     │           0 │
conv3_block1_out… │
│ (Add)               │ 512)               │             │
conv3_block2_3_b… │
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block2_out    │ (None, 28, 28,     │           0 │
conv3_block2_add… │
│ (Activation)        │ 512)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block3_1_conv │ (None, 28, 28,     │      65,664 │
conv3_block2_out… │
│ (Conv2D)            │ 128)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
```

```
│ conv3_block3_1_bn   │ (None, 28, 28,     │         512 │
conv3_block3_1_c… │
│ (BatchNormalizatio… │ 128)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block3_1_relu │ (None, 28, 28,     │           0 │
conv3_block3_1_b… │
│ (Activation)        │ 128)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block3_2_conv │ (None, 28, 28,     │     147,584 │
conv3_block3_1_r… │
│ (Conv2D)            │ 128)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block3_2_bn   │ (None, 28, 28,     │         512 │
conv3_block3_2_c… │
│ (BatchNormalizatio… │ 128)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block3_2_relu │ (None, 28, 28,     │           0 │
conv3_block3_2_b… │
│ (Activation)        │ 128)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block3_3_conv │ (None, 28, 28,     │      66,048 │
conv3_block3_2_r… │
│ (Conv2D)            │ 512)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block3_3_bn   │ (None, 28, 28,     │       2,048 │
conv3_block3_3_c… │
│ (BatchNormalizatio… │ 512)               │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block3_add    │ (None, 28, 28,     │           0 │
conv3_block2_out… │
│ (Add)               │ 512)               │             │
conv3_block3_3_b… │
├─────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ conv3_block3_out    │ (None, 28, 28,     │           0 │
conv3_block3_add… │
│ (Activation)        │ 512)              │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv3_block4_1_conv │ (None, 28, 28,    │      65,664 │
conv3_block3_out… │
│ (Conv2D)            │ 128)              │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv3_block4_1_bn   │ (None, 28, 28,    │         512 │
conv3_block4_1_c… │
│ (BatchNormalizatio… │ 128)              │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv3_block4_1_relu │ (None, 28, 28,    │           0 │
conv3_block4_1_b… │
│ (Activation)        │ 128)              │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv3_block4_2_conv │ (None, 28, 28,    │     147,584 │
conv3_block4_1_r… │
│ (Conv2D)            │ 128)              │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv3_block4_2_bn   │ (None, 28, 28,    │         512 │
conv3_block4_2_c… │
│ (BatchNormalizatio… │ 128)              │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv3_block4_2_relu │ (None, 28, 28,    │           0 │
conv3_block4_2_b… │
│ (Activation)        │ 128)              │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv3_block4_3_conv │ (None, 28, 28,    │      66,048 │
conv3_block4_2_r… │
│ (Conv2D)            │ 512)              │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv3_block4_3_bn   │ (None, 28, 28,    │       2,048 │
conv3_block4_3_c… │
```

```
│ (BatchNormalizatio… │ 512)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ conv3_block4_add    │ (None, 28, 28,    │          0 │
conv3_block3_out… │
│ (Add)               │ 512)              │            │
conv3_block4_3_b… │
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ conv3_block4_out    │ (None, 28, 28,    │          0 │
conv3_block4_add… │
│ (Activation)        │ 512)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ conv4_block1_1_conv │ (None, 14, 14,    │    131,328 │
conv3_block4_out… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ conv4_block1_1_bn   │ (None, 14, 14,    │      1,024 │
conv4_block1_1_c… │
│ (BatchNormalizatio… │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ conv4_block1_1_relu │ (None, 14, 14,    │          0 │
conv4_block1_1_b… │
│ (Activation)        │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ conv4_block1_2_conv │ (None, 14, 14,    │    590,080 │
conv4_block1_1_r… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ conv4_block1_2_bn   │ (None, 14, 14,    │      1,024 │
conv4_block1_2_c… │
│ (BatchNormalizatio… │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ conv4_block1_2_relu │ (None, 14, 14,    │          0 │
conv4_block1_2_b… │
│ (Activation)        │ 256)              │            │
│
```

```
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block1_0_conv │ (None, 14, 14,    │    525,312 │
conv3_block4_out… │
│ (Conv2D)            │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block1_3_conv │ (None, 14, 14,    │    263,168 │
conv4_block1_2_r… │
│ (Conv2D)            │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block1_0_bn   │ (None, 14, 14,    │      4,096 │
conv4_block1_0_c… │
│ (BatchNormalizatio… │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block1_3_bn   │ (None, 14, 14,    │      4,096 │
conv4_block1_3_c… │
│ (BatchNormalizatio… │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block1_add    │ (None, 14, 14,    │          0 │
conv4_block1_0_b… │
│ (Add)               │ 1024)             │            │
conv4_block1_3_b… │
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block1_out    │ (None, 14, 14,    │          0 │
conv4_block1_add… │
│ (Activation)        │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block2_1_conv │ (None, 14, 14,    │    262,400 │
conv4_block1_out… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block2_1_bn   │ (None, 14, 14,    │      1,024 │
conv4_block2_1_c… │
│ (BatchNormalizatio… │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
```

```
─────┤
│ conv4_block2_1_relu │ (None, 14, 14,    │          0 │
conv4_block2_1_b… │
│ (Activation)        │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block2_2_conv │ (None, 14, 14,    │    590,080 │
conv4_block2_1_r… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block2_2_bn   │ (None, 14, 14,    │      1,024 │
conv4_block2_2_c… │
│ (BatchNormalizatio… │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block2_2_relu │ (None, 14, 14,    │          0 │
conv4_block2_2_b… │
│ (Activation)        │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block2_3_conv │ (None, 14, 14,    │    263,168 │
conv4_block2_2_r… │
│ (Conv2D)            │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block2_3_bn   │ (None, 14, 14,    │      4,096 │
conv4_block2_3_c… │
│ (BatchNormalizatio… │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block2_add    │ (None, 14, 14,    │          0 │
conv4_block1_out… │
│ (Add)               │ 1024)             │            │
conv4_block2_3_b… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block2_out    │ (None, 14, 14,    │          0 │
conv4_block2_add… │
│ (Activation)        │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
```

```
│ conv4_block3_1_conv │ (None, 14, 14,      │    262,400 │
conv4_block2_out… │
│ (Conv2D)            │ 256)                │            │
│
├─────────────────────┼─────────────────────┼────────────┼──────────────
─────┤
│ conv4_block3_1_bn   │ (None, 14, 14,      │      1,024 │
conv4_block3_1_c… │
│ (BatchNormalizatio… │ 256)                │            │
│
├─────────────────────┼─────────────────────┼────────────┼──────────────
─────┤
│ conv4_block3_1_relu │ (None, 14, 14,      │          0 │
conv4_block3_1_b… │
│ (Activation)        │ 256)                │            │
│
├─────────────────────┼─────────────────────┼────────────┼──────────────
─────┤
│ conv4_block3_2_conv │ (None, 14, 14,      │    590,080 │
conv4_block3_1_r… │
│ (Conv2D)            │ 256)                │            │
│
├─────────────────────┼─────────────────────┼────────────┼──────────────
─────┤
│ conv4_block3_2_bn   │ (None, 14, 14,      │      1,024 │
conv4_block3_2_c… │
│ (BatchNormalizatio… │ 256)                │            │
│
├─────────────────────┼─────────────────────┼────────────┼──────────────
─────┤
│ conv4_block3_2_relu │ (None, 14, 14,      │          0 │
conv4_block3_2_b… │
│ (Activation)        │ 256)                │            │
│
├─────────────────────┼─────────────────────┼────────────┼──────────────
─────┤
│ conv4_block3_3_conv │ (None, 14, 14,      │    263,168 │
conv4_block3_2_r… │
│ (Conv2D)            │ 1024)               │            │
│
├─────────────────────┼─────────────────────┼────────────┼──────────────
─────┤
│ conv4_block3_3_bn   │ (None, 14, 14,      │      4,096 │
conv4_block3_3_c… │
│ (BatchNormalizatio… │ 1024)               │            │
│
├─────────────────────┼─────────────────────┼────────────┼──────────────
─────┤
│ conv4_block3_add    │ (None, 14, 14,      │          0 │
conv4_block2_out… │
│ (Add)                │ 1024)               │            │
conv4_block3_3_b… │
├──────────────────────┼─────────────────────┼────────────┼──────────────
──────┤
│ conv4_block3_out     │ (None, 14, 14,      │          0 │
conv4_block3_add… │
│ (Activation)         │ 1024)               │            │
│
├──────────────────────┼─────────────────────┼────────────┼──────────────
──────┤
│ conv4_block4_1_conv │ (None, 14, 14,      │    262,400 │
conv4_block3_out… │
│ (Conv2D)             │ 256)                │            │
│
├──────────────────────┼─────────────────────┼────────────┼──────────────
──────┤
│ conv4_block4_1_bn    │ (None, 14, 14,      │      1,024 │
conv4_block4_1_c… │
│ (BatchNormalizatio… │ 256)                │            │
│
├──────────────────────┼─────────────────────┼────────────┼──────────────
──────┤
│ conv4_block4_1_relu │ (None, 14, 14,      │          0 │
conv4_block4_1_b… │
│ (Activation)         │ 256)                │            │
│
├──────────────────────┼─────────────────────┼────────────┼──────────────
──────┤
│ conv4_block4_2_conv │ (None, 14, 14,      │    590,080 │
conv4_block4_1_r… │
│ (Conv2D)             │ 256)                │            │
│
├──────────────────────┼─────────────────────┼────────────┼──────────────
──────┤
│ conv4_block4_2_bn    │ (None, 14, 14,      │      1,024 │
conv4_block4_2_c… │
│ (BatchNormalizatio… │ 256)                │            │
│
├──────────────────────┼─────────────────────┼────────────┼──────────────
──────┤
│ conv4_block4_2_relu │ (None, 14, 14,      │          0 │
conv4_block4_2_b… │
│ (Activation)         │ 256)                │            │
│
├──────────────────────┼─────────────────────┼────────────┼──────────────
──────┤
│ conv4_block4_3_conv │ (None, 14, 14,      │    263,168 │
conv4_block4_2_r… │
```

```
│ (Conv2D)            │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
──────┤
│ conv4_block4_3_bn   │ (None, 14, 14,    │      4,096 │
conv4_block4_3_c… │
│ (BatchNormalizatio… │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
──────┤
│ conv4_block4_add    │ (None, 14, 14,    │          0 │
conv4_block3_out… │
│ (Add)               │ 1024)             │            │
conv4_block4_3_b… │
├─────────────────────┼───────────────────┼────────────┼───────────────
──────┤
│ conv4_block4_out    │ (None, 14, 14,    │          0 │
conv4_block4_add… │
│ (Activation)        │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
──────┤
│ conv4_block5_1_conv │ (None, 14, 14,    │    262,400 │
conv4_block4_out… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
──────┤
│ conv4_block5_1_bn   │ (None, 14, 14,    │      1,024 │
conv4_block5_1_c… │
│ (BatchNormalizatio… │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
──────┤
│ conv4_block5_1_relu │ (None, 14, 14,    │          0 │
conv4_block5_1_b… │
│ (Activation)        │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
──────┤
│ conv4_block5_2_conv │ (None, 14, 14,    │    590,080 │
conv4_block5_1_r… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
──────┤
│ conv4_block5_2_bn   │ (None, 14, 14,    │      1,024 │
conv4_block5_2_c… │
│ (BatchNormalizatio… │ 256)              │            │
```

```
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block5_2_relu │ (None, 14, 14,    │          0 │
conv4_block5_2_b… │
│ (Activation)        │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block5_3_conv │ (None, 14, 14,    │    263,168 │
conv4_block5_2_r… │
│ (Conv2D)            │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block5_3_bn   │ (None, 14, 14,    │      4,096 │
conv4_block5_3_c… │
│ (BatchNormalizatio… │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block5_add    │ (None, 14, 14,    │          0 │
conv4_block4_out… │
│ (Add)               │ 1024)             │            │
conv4_block5_3_b… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block5_out    │ (None, 14, 14,    │          0 │
conv4_block5_add… │
│ (Activation)        │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block6_1_conv │ (None, 14, 14,    │    262,400 │
conv4_block5_out… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block6_1_bn   │ (None, 14, 14,    │      1,024 │
conv4_block6_1_c… │
│ (BatchNormalizatio… │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv4_block6_1_relu │ (None, 14, 14,    │          0 │
conv4_block6_1_b… │
│ (Activation)        │ 256)              │            │
│
```

```
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block6_2_conv │ (None, 14, 14,    │    590,080 │
conv4_block6_1_r… │
│ (Conv2D)            │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block6_2_bn   │ (None, 14, 14,    │      1,024 │
conv4_block6_2_c… │
│ (BatchNormalizatio… │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block6_2_relu │ (None, 14, 14,    │          0 │
conv4_block6_2_b… │
│ (Activation)        │ 256)              │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block6_3_conv │ (None, 14, 14,    │    263,168 │
conv4_block6_2_r… │
│ (Conv2D)            │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block6_3_bn   │ (None, 14, 14,    │      4,096 │
conv4_block6_3_c… │
│ (BatchNormalizatio… │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block6_add    │ (None, 14, 14,    │          0 │
conv4_block5_out… │
│ (Add)               │ 1024)             │            │
conv4_block6_3_b… │
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv4_block6_out    │ (None, 14, 14,    │          0 │
conv4_block6_add… │
│ (Activation)        │ 1024)             │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ conv5_block1_1_conv │ (None, 7, 7, 512) │    524,800 │
conv4_block6_out… │
│ (Conv2D)            │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
```

```
─────┤
│ conv5_block1_1_bn   │ (None, 7, 7, 512) │       2,048 │
conv5_block1_1_c… │
│ (BatchNormalizatio… │                   │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv5_block1_1_relu │ (None, 7, 7, 512) │           0 │
conv5_block1_1_b… │
│ (Activation)        │                   │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv5_block1_2_conv │ (None, 7, 7, 512) │   2,359,808 │
conv5_block1_1_r… │
│ (Conv2D)            │                   │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv5_block1_2_bn   │ (None, 7, 7, 512) │       2,048 │
conv5_block1_2_c… │
│ (BatchNormalizatio… │                   │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv5_block1_2_relu │ (None, 7, 7, 512) │           0 │
conv5_block1_2_b… │
│ (Activation)        │                   │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv5_block1_0_conv │ (None, 7, 7,      │   2,099,200 │
conv4_block6_out… │
│ (Conv2D)            │ 2048)             │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv5_block1_3_conv │ (None, 7, 7,      │   1,050,624 │
conv5_block1_2_r… │
│ (Conv2D)            │ 2048)             │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
│ conv5_block1_0_bn   │ (None, 7, 7,      │       8,192 │
conv5_block1_0_c… │
│ (BatchNormalizatio… │ 2048)             │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
─────┤
```

```
│ conv5_block1_3_bn   │ (None, 7, 7,      │      8,192 │
conv5_block1_3_c… │
│ (BatchNormalizatio… │ 2048)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block1_add    │ (None, 7, 7,      │          0 │
conv5_block1_0_b… │
│ (Add)               │ 2048)             │            │
conv5_block1_3_b… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block1_out    │ (None, 7, 7,      │          0 │
conv5_block1_add… │
│ (Activation)        │ 2048)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_1_conv │ (None, 7, 7, 512) │  1,049,088 │
conv5_block1_out… │
│ (Conv2D)            │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_1_bn   │ (None, 7, 7, 512) │      2,048 │
conv5_block2_1_c… │
│ (BatchNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_1_relu │ (None, 7, 7, 512) │          0 │
conv5_block2_1_b… │
│ (Activation)        │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_2_conv │ (None, 7, 7, 512) │  2,359,808 │
conv5_block2_1_r… │
│ (Conv2D)            │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_2_bn   │ (None, 7, 7, 512) │      2,048 │
conv5_block2_2_c… │
│ (BatchNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_2_relu │ (None, 7, 7, 512) │          0 │
```

```
conv5_block2_2_b… │
│ (Activation)        │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_3_conv │ (None, 7, 7,      │  1,050,624 │
conv5_block2_2_r… │
│ (Conv2D)            │ 2048)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_3_bn   │ (None, 7, 7,      │      8,192 │
conv5_block2_3_c… │
│ (BatchNormalizatio… │ 2048)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_add    │ (None, 7, 7,      │          0 │
conv5_block1_out… │
│ (Add)               │ 2048)             │            │
conv5_block2_3_b… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block2_out    │ (None, 7, 7,      │          0 │
conv5_block2_add… │
│ (Activation)        │ 2048)             │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block3_1_conv │ (None, 7, 7, 512) │  1,049,088 │
conv5_block2_out… │
│ (Conv2D)            │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block3_1_bn   │ (None, 7, 7, 512) │      2,048 │
conv5_block3_1_c… │
│ (BatchNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block3_1_relu │ (None, 7, 7, 512) │          0 │
conv5_block3_1_b… │
│ (Activation)        │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv5_block3_2_conv │ (None, 7, 7, 512) │  2,359,808 │
conv5_block3_1_r… │
```

```
│ (Conv2D)            │                   │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv5_block3_2_bn   │ (None, 7, 7, 512) │       2,048 │
conv5_block3_2_c… │
│ (BatchNormalizatio… │                   │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv5_block3_2_relu │ (None, 7, 7, 512) │           0 │
conv5_block3_2_b… │
│ (Activation)        │                   │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv5_block3_3_conv │ (None, 7, 7,      │   1,050,624 │
conv5_block3_2_r… │
│ (Conv2D)            │ 2048)             │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv5_block3_3_bn   │ (None, 7, 7,      │       8,192 │
conv5_block3_3_c… │
│ (BatchNormalizatio… │ 2048)             │             │
│
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv5_block3_add    │ (None, 7, 7,      │           0 │
conv5_block2_out… │
│ (Add)               │ 2048)             │             │
conv5_block3_3_b… │
├─────────────────────┼───────────────────┼─────────────┼──────────────
──────┤
│ conv5_block3_out    │ (None, 7, 7,      │           0 │
conv5_block3_add… │
│ (Activation)        │ 2048)             │             │
│
└─────────────────────┴───────────────────┴─────────────┴──────────────
──────┘

 Total params: 23,587,712 (89.98 MB)

 Trainable params: 0 (0.00 B)

 Non-trainable params: 23,587,712 (89.98 MB)
```

Nous avons récupéré le réseau ResNet50 car il est plus petit, donc plus adapté à notre petit dataset, et il a de très bonnes performances. Nous avons désactivé chaque couche de convolution car nous ne possédons pas un dataset assez gros pour modifier les poids. Nous avons enlevé les couches fully connected pour qu'il s'entraîne sur nos données.

```
def create_final_model(pre_trained_model, last_output):
    # Aplatir la couche de sortie
    x = layers.GlobalAveragePooling2D()(pre_trained_model.layers[-
1].output)
    x = layers.Dense(2048, activation='relu')(x)
    x = layers.Dropout(0.2)(x)
    x = layers.Dense(256, activation='relu')(x)
    x = layers.Dropout(0.2)(x)
    x = layers.Dense(3, activation='softmax')(x)

    # Créer le modèle complet
    model = Model(inputs=pre_trained_model.input, outputs=x)

    model.compile(optimizer=Adam(learning_rate=0.0001),
                  loss='categorical_crossentropy',
                  metrics=['accuracy'])

    return model

model = create_final_model(pre_trained_model,
pre_trained_model.output)
# Inspect parameters
total_params = model.count_params()
num_trainable_params = sum([w.shape.num_elements() for w in
model.trainable_weights])

print(f"There are {total_params:,} total parameters in this model.")
print(f"There are {num_trainable_params:,} trainable parameters in
this model.")
```

```
There are 28,309,379 total parameters in this model.
There are 4,721,667 trainable parameters in this model.
```

```
#Vu que les classes sont désequilibrié, soit il faut generer des
images par classes,
#soit rajouter des poids au classe
class_weight = {
    0: 0.524,  # Colonial # 236/(150*3)
    1: 2.313,  # Modern # 236/(34*3)
    2: 1.512  # Prehispanic # 236/(52*3)
}


earlyStopping = EarlyStopping(monitor='val_loss', patience=10,
verbose=0, mode='min')
mcp_save = ModelCheckpoint('bestModel.keras', save_best_only=True,
monitor='val_loss', mode='min')
reduce_lr_loss = ReduceLROnPlateau(monitor='val_loss', factor=0.1,
```

```python
patience=7, verbose=1, epsilon=1e-4, mode='min')

val_images, val_labels = next(iter(validation_generator))


history = model.fit(train_generator,
                    validation_data = validation_generator,
                    epochs = 60,
                    callbacks=[earlyStopping, mcp_save,
reduce_lr_loss],
                    verbose=2,
                    class_weight=class_weight)
```

```
Epoch 1/60
```

```
/opt/anaconda3/lib/python3.11/site-packages/keras/src/trainers/
data_adapters/py_dataset_adapter.py:120: UserWarning: Your `PyDataset`
class should call `super().__init__(**kwargs)` in its constructor.
`**kwargs` can include `workers`, `use_multiprocessing`,
`max_queue_size`. Do not pass these arguments to `fit()`, as they will
be ignored.
  self._warn_if_super_not_called()
```

```
8/8 - 32s - 4s/step - accuracy: 0.3559 - loss: 1.1405 - val_accuracy:
0.3542 - val_loss: 1.0642 - learning_rate: 1.0000e-04
Epoch 2/60
8/8 - 24s - 3s/step - accuracy: 0.3390 - loss: 1.1398 - val_accuracy:
0.4167 - val_loss: 1.0614 - learning_rate: 1.0000e-04
Epoch 3/60
8/8 - 24s - 3s/step - accuracy: 0.4153 - loss: 1.1305 - val_accuracy:
0.5208 - val_loss: 1.0264 - learning_rate: 1.0000e-04
Epoch 4/60
8/8 - 24s - 3s/step - accuracy: 0.4322 - loss: 1.0738 - val_accuracy:
0.3333 - val_loss: 1.0400 - learning_rate: 1.0000e-04
Epoch 5/60
8/8 - 25s - 3s/step - accuracy: 0.3898 - loss: 1.0899 - val_accuracy:
0.4375 - val_loss: 1.0115 - learning_rate: 1.0000e-04
Epoch 6/60
8/8 - 24s - 3s/step - accuracy: 0.4873 - loss: 1.0523 - val_accuracy:
0.6042 - val_loss: 0.9791 - learning_rate: 1.0000e-04
Epoch 7/60
8/8 - 24s - 3s/step - accuracy: 0.4110 - loss: 1.0153 - val_accuracy:
0.5833 - val_loss: 0.9663 - learning_rate: 1.0000e-04
Epoch 8/60
8/8 - 24s - 3s/step - accuracy: 0.5975 - loss: 0.9775 - val_accuracy:
0.5625 - val_loss: 0.9617 - learning_rate: 1.0000e-04
Epoch 9/60
8/8 - 25s - 3s/step - accuracy: 0.3814 - loss: 0.9718 - val_accuracy:
0.5833 - val_loss: 0.9550 - learning_rate: 1.0000e-04
Epoch 10/60
```

```
8/8 - 24s - 3s/step - accuracy: 0.5847 - loss: 0.9124 - val_accuracy:
0.5208 - val_loss: 0.9771 - learning_rate: 1.0000e-04
Epoch 11/60
8/8 - 24s - 3s/step - accuracy: 0.6610 - loss: 1.0048 - val_accuracy:
0.4792 - val_loss: 0.9626 - learning_rate: 1.0000e-04
Epoch 12/60
8/8 - 24s - 3s/step - accuracy: 0.4237 - loss: 0.9305 - val_accuracy:
0.5833 - val_loss: 0.9373 - learning_rate: 1.0000e-04
Epoch 13/60
8/8 - 24s - 3s/step - accuracy: 0.5551 - loss: 0.9447 - val_accuracy:
0.5417 - val_loss: 0.9410 - learning_rate: 1.0000e-04
Epoch 14/60
8/8 - 24s - 3s/step - accuracy: 0.6441 - loss: 0.9411 - val_accuracy:
0.6042 - val_loss: 0.9209 - learning_rate: 1.0000e-04
Epoch 15/60
8/8 - 24s - 3s/step - accuracy: 0.4576 - loss: 0.9230 - val_accuracy:
0.5000 - val_loss: 0.9387 - learning_rate: 1.0000e-04
Epoch 16/60
8/8 - 24s - 3s/step - accuracy: 0.6186 - loss: 0.8997 - val_accuracy:
0.5833 - val_loss: 0.9098 - learning_rate: 1.0000e-04
Epoch 17/60
8/8 - 24s - 3s/step - accuracy: 0.5805 - loss: 0.8740 - val_accuracy:
0.5833 - val_loss: 0.8928 - learning_rate: 1.0000e-04
Epoch 18/60
8/8 - 24s - 3s/step - accuracy: 0.5932 - loss: 0.8803 - val_accuracy:
0.6042 - val_loss: 0.8924 - learning_rate: 1.0000e-04
Epoch 19/60
8/8 - 24s - 3s/step - accuracy: 0.6186 - loss: 0.8306 - val_accuracy:
0.5833 - val_loss: 0.8975 - learning_rate: 1.0000e-04
Epoch 20/60
8/8 - 24s - 3s/step - accuracy: 0.6017 - loss: 0.8403 - val_accuracy:
0.5833 - val_loss: 0.8769 - learning_rate: 1.0000e-04
Epoch 21/60
8/8 - 24s - 3s/step - accuracy: 0.6271 - loss: 0.8213 - val_accuracy:
0.5833 - val_loss: 0.8784 - learning_rate: 1.0000e-04
Epoch 22/60
8/8 - 24s - 3s/step - accuracy: 0.6356 - loss: 0.8392 - val_accuracy:
0.5833 - val_loss: 0.8681 - learning_rate: 1.0000e-04
Epoch 23/60
8/8 - 25s - 3s/step - accuracy: 0.7203 - loss: 0.8510 - val_accuracy:
0.5625 - val_loss: 0.9016 - learning_rate: 1.0000e-04
Epoch 24/60
8/8 - 24s - 3s/step - accuracy: 0.6102 - loss: 0.8055 - val_accuracy:
0.6042 - val_loss: 0.8702 - learning_rate: 1.0000e-04
Epoch 25/60
8/8 - 26s - 3s/step - accuracy: 0.6695 - loss: 0.8241 - val_accuracy:
0.6042 - val_loss: 0.8825 - learning_rate: 1.0000e-04
Epoch 26/60
8/8 - 24s - 3s/step - accuracy: 0.6059 - loss: 0.8157 - val_accuracy:
```

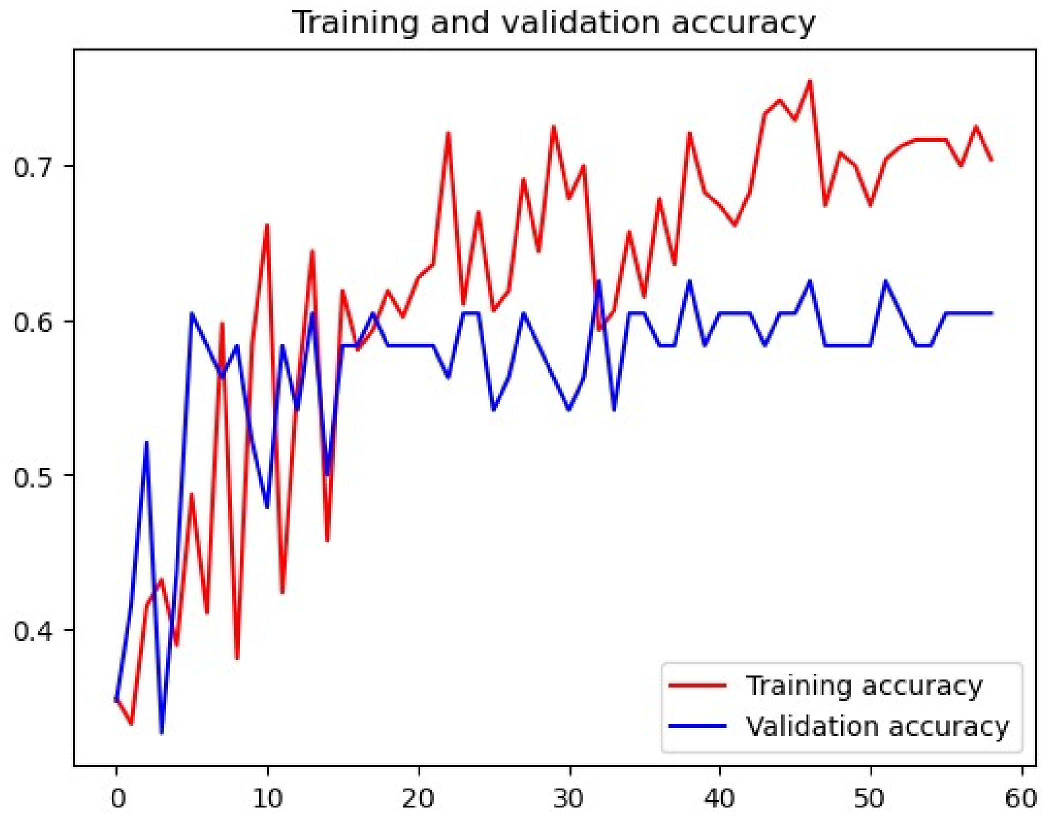
```
0.5417 - val_loss: 0.8749 - learning_rate: 1.0000e-04
Epoch 27/60
8/8 - 24s - 3s/step - accuracy: 0.6186 - loss: 0.7755 - val_accuracy:
0.5625 - val_loss: 0.8604 - learning_rate: 1.0000e-04
Epoch 28/60
8/8 - 24s - 3s/step - accuracy: 0.6907 - loss: 0.8017 - val_accuracy:
0.6042 - val_loss: 0.8510 - learning_rate: 1.0000e-04
Epoch 29/60
8/8 - 24s - 3s/step - accuracy: 0.6441 - loss: 0.7785 - val_accuracy:
0.5833 - val_loss: 0.8444 - learning_rate: 1.0000e-04
Epoch 30/60
8/8 - 25s - 3s/step - accuracy: 0.7246 - loss: 0.7766 - val_accuracy:
0.5625 - val_loss: 0.8627 - learning_rate: 1.0000e-04
Epoch 31/60
8/8 - 25s - 3s/step - accuracy: 0.6780 - loss: 0.7242 - val_accuracy:
0.5417 - val_loss: 0.8368 - learning_rate: 1.0000e-04
Epoch 32/60
8/8 - 26s - 3s/step - accuracy: 0.6992 - loss: 0.7420 - val_accuracy:
0.5625 - val_loss: 0.8935 - learning_rate: 1.0000e-04
Epoch 33/60
8/8 - 26s - 3s/step - accuracy: 0.5932 - loss: 0.7839 - val_accuracy:
0.6250 - val_loss: 0.8984 - learning_rate: 1.0000e-04
Epoch 34/60
8/8 - 24s - 3s/step - accuracy: 0.6059 - loss: 0.8181 - val_accuracy:
0.5417 - val_loss: 0.9123 - learning_rate: 1.0000e-04
Epoch 35/60
8/8 - 24s - 3s/step - accuracy: 0.6568 - loss: 0.7552 - val_accuracy:
0.6042 - val_loss: 0.8275 - learning_rate: 1.0000e-04
Epoch 36/60
8/8 - 25s - 3s/step - accuracy: 0.6144 - loss: 0.7275 - val_accuracy:
0.6042 - val_loss: 0.8279 - learning_rate: 1.0000e-04
Epoch 37/60
8/8 - 24s - 3s/step - accuracy: 0.6780 - loss: 0.7351 - val_accuracy:
0.5833 - val_loss: 0.8571 - learning_rate: 1.0000e-04
Epoch 38/60
8/8 - 24s - 3s/step - accuracy: 0.6356 - loss: 0.7082 - val_accuracy:
0.5833 - val_loss: 0.8424 - learning_rate: 1.0000e-04
Epoch 39/60
8/8 - 24s - 3s/step - accuracy: 0.7203 - loss: 0.6994 - val_accuracy:
0.6250 - val_loss: 0.8369 - learning_rate: 1.0000e-04
Epoch 40/60
8/8 - 24s - 3s/step - accuracy: 0.6822 - loss: 0.7288 - val_accuracy:
0.5833 - val_loss: 0.8594 - learning_rate: 1.0000e-04
Epoch 41/60
8/8 - 24s - 3s/step - accuracy: 0.6737 - loss: 0.7144 - val_accuracy:
0.6042 - val_loss: 0.8291 - learning_rate: 1.0000e-04
Epoch 42/60

Epoch 42: ReduceLROnPlateau reducing learning rate to
```

```
9.999999747378752e-06.
8/8 - 24s - 3s/step - accuracy: 0.6610 - loss: 0.6882 - val_accuracy:
0.6042 - val_loss: 0.8276 - learning_rate: 1.0000e-04
Epoch 43/60
8/8 - 24s - 3s/step - accuracy: 0.6822 - loss: 0.6515 - val_accuracy:
0.6042 - val_loss: 0.8226 - learning_rate: 1.0000e-05
Epoch 44/60
8/8 - 24s - 3s/step - accuracy: 0.7331 - loss: 0.6247 - val_accuracy:
0.5833 - val_loss: 0.8223 - learning_rate: 1.0000e-05
Epoch 45/60
8/8 - 24s - 3s/step - accuracy: 0.7415 - loss: 0.6742 - val_accuracy:
0.6042 - val_loss: 0.8243 - learning_rate: 1.0000e-05
Epoch 46/60
8/8 - 23s - 3s/step - accuracy: 0.7288 - loss: 0.6771 - val_accuracy:
0.6042 - val_loss: 0.8268 - learning_rate: 1.0000e-05
Epoch 47/60
8/8 - 15s - 2s/step - accuracy: 0.7542 - loss: 0.6260 - val_accuracy:
0.6250 - val_loss: 0.8309 - learning_rate: 1.0000e-05
Epoch 48/60
8/8 - 13s - 2s/step - accuracy: 0.6737 - loss: 0.6602 - val_accuracy:
0.5833 - val_loss: 0.8235 - learning_rate: 1.0000e-05
Epoch 49/60
8/8 - 14s - 2s/step - accuracy: 0.7076 - loss: 0.6265 - val_accuracy:
0.5833 - val_loss: 0.8210 - learning_rate: 1.0000e-05
Epoch 50/60
8/8 - 14s - 2s/step - accuracy: 0.6992 - loss: 0.6843 - val_accuracy:
0.5833 - val_loss: 0.8223 - learning_rate: 1.0000e-05
Epoch 51/60
8/8 - 14s - 2s/step - accuracy: 0.6737 - loss: 0.6797 - val_accuracy:
0.5833 - val_loss: 0.8242 - learning_rate: 1.0000e-05
Epoch 52/60
8/8 - 14s - 2s/step - accuracy: 0.7034 - loss: 0.6733 - val_accuracy:
0.6250 - val_loss: 0.8319 - learning_rate: 1.0000e-05
Epoch 53/60
8/8 - 14s - 2s/step - accuracy: 0.7119 - loss: 0.6822 - val_accuracy:
0.6042 - val_loss: 0.8264 - learning_rate: 1.0000e-05
Epoch 54/60
8/8 - 14s - 2s/step - accuracy: 0.7161 - loss: 0.6545 - val_accuracy:
0.5833 - val_loss: 0.8245 - learning_rate: 1.0000e-05
Epoch 55/60
8/8 - 14s - 2s/step - accuracy: 0.7161 - loss: 0.6636 - val_accuracy:
0.5833 - val_loss: 0.8224 - learning_rate: 1.0000e-05
Epoch 56/60

Epoch 56: ReduceLROnPlateau reducing learning rate to
9.999999747378752e-07.
8/8 - 14s - 2s/step - accuracy: 0.7161 - loss: 0.6550 - val_accuracy:
0.6042 - val_loss: 0.8258 - learning_rate: 1.0000e-05
Epoch 57/60
```

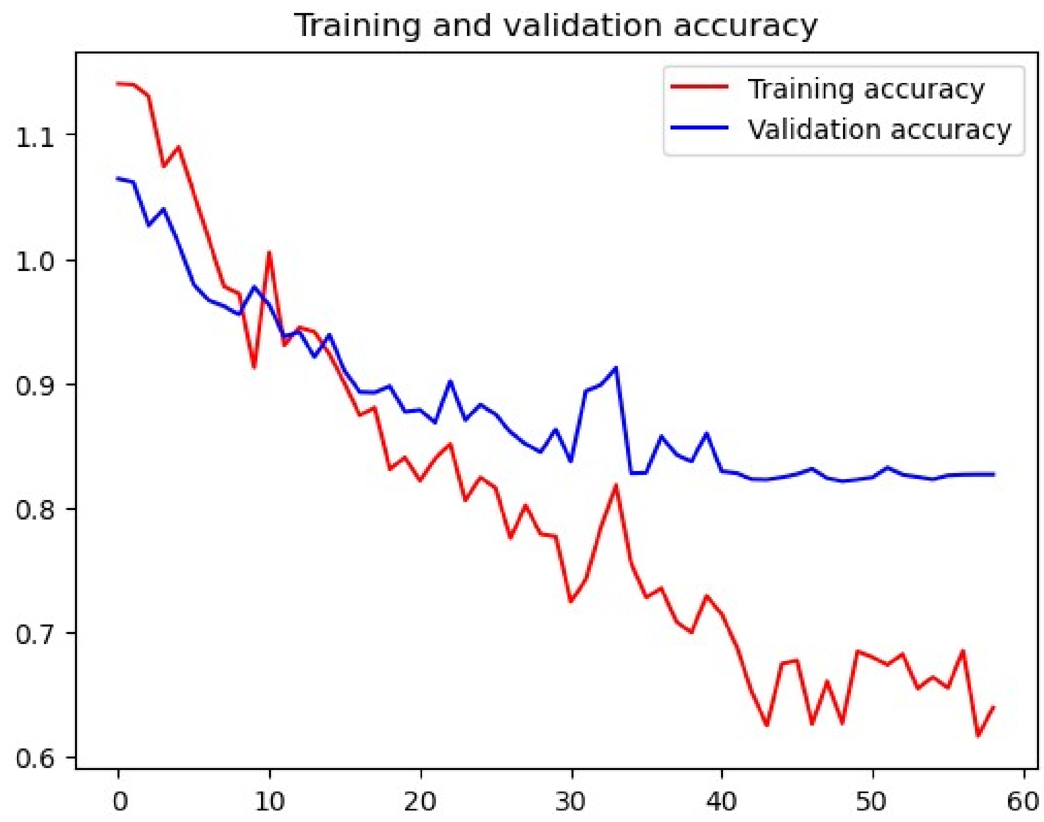
```
8/8 - 15s - 2s/step - accuracy: 0.6992 - loss: 0.6848 - val_accuracy:
0.6042 - val_loss: 0.8264 - learning_rate: 1.0000e-06
Epoch 58/60
8/8 - 14s - 2s/step - accuracy: 0.7246 - loss: 0.6164 - val_accuracy:
0.6042 - val_loss: 0.8266 - learning_rate: 1.0000e-06
Epoch 59/60
8/8 - 14s - 2s/step - accuracy: 0.7034 - loss: 0.6391 - val_accuracy:
0.6042 - val_loss: 0.8266 - learning_rate: 1.0000e-06
```

Performance

```python
# Plot the training and validation accuracies for each epoch

acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
loss = history.history['loss']
val_loss = history.history['val_loss']

epochs = range(len(acc))

plt.plot(epochs, acc, 'r', label='Training accuracy')
plt.plot(epochs, val_acc, 'b', label='Validation accuracy')
plt.title('Training and validation accuracy')
plt.legend(loc=0)
plt.figure()

plt.show()

plt.plot(epochs, loss, 'r', label='Training accuracy')
plt.plot(epochs, val_loss, 'b', label='Validation accuracy')
plt.title('Training and validation accuracy')
plt.legend(loc=0)
plt.figure()

plt.show()
```


Training and validation accuracy
0.7
0.6
0.5
0.4
0
10
20
30
40
50
60
Training accuracy
Validation accuracy

```
<Figure size 640x480 with 0 Axes>
```



```
<Figure size 640x480 with 0 Axes>
```

On peut constater qu'il faut baisser le learning rate car il est en dents de scie

Chargement du meilleur model de validation

```python
model = keras.saving.load_model('bestModel.keras')
```

Sur les données de validation

```python
import numpy as np
from sklearn.metrics import classification_report

# Supposons que validation_generator est déjà défini
val_images, val_labels = next(iter(validation_generator))  # Obtenir un lot d'images et d'étiquettes de validation

# Faire des prédictions sur les données de validation
predictions = model.predict(val_images)

# Convertir les prédictions en classes
predicted_classes = np.argmax(predictions, axis=1)
true_classes = np.argmax(val_labels, axis=1)

report = classification_report(true_classes, predicted_classes,
output_dict=True)

# Afficher l'accuracy pour chaque classe
for class_label, metrics in report.items():
    if isinstance(metrics, dict):  # Pour éviter les entrées non-
classe comme 'accuracy' globale
        print(f"Classe {class_label}: Accuracy =
{metrics['precision']:.2f}")
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 1s 1s/step
Classe 0: Accuracy = 0.33
Classe 1: Accuracy = 0.29
Classe 2: Accuracy = 0.67
Classe macro avg: Accuracy = 0.43
Classe weighted avg: Accuracy = 0.46
```

On peut voir que la classe Modern a toujours du malgrès les poids sur les classes ; ainsi, il aurait quand meme fallu augmenter le dataset

```
def is_image_in_list(image, image_list):
    for img in image_list:
        if np.array_equal(image, img[0]):
            return True
    return False

val_images, val_labels = next(iter(validation_generator))

# Faire des prédictions
predictions = model.predict(val_images)
predicted_classes = np.argmax(predictions, axis=1)
true_classes = np.argmax(val_labels, axis=1)

# Identifier les prédictions incorrectes
wrong_predictions = []

def save_image(predictions_list, condition, comparator):
    for i in range(len(val_images)):
        if condition(predicted_classes[i], true_classes[i]):
            # Enregistrer l'image, la prédiction et le score
d'exactitude
            accuracy = comparator(predictions[i])  # Utiliser les
prédictions actuelles
            if not is_image_in_list(val_images[i], predictions_list):
                predictions_list.append((val_images[i],
predicted_classes[i], accuracy))
    return predictions_list  # Correction pour retourner la liste des
prédictions

# Utilisation des opérateurs pour les conditions
```

```
wrong_predictions = save_image(wrong_predictions, lambda pred, true:
pred != true, np.max)
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 2s 2s/step
```

```
def plot_top_predictions(predictions, top_n=10):
    # Trier les prédictions par score
    predictions.sort(key=lambda x: x[2], reverse=True)  # Trier par
précision

    # Afficher les images avec les scores les plus élevés
    plt.figure(figsize=(15, 10))
    for i in range(min(top_n, len(predictions))):
        img, pred_class, accuracy = predictions[i]
        plt.subplot(2, 5, i + 1)
        plt.imshow(img)
        plt.title(f'Pred: {pred_class}, Acc: {accuracy:.2f}')
        plt.axis('off')
    plt.show()

print("_____Wrong Predictions_____")
plot_top_predictions(wrong_predictions, top_n=10)
```

```
_____Wrong Predictions_____
```