

# CNN – Classification Intel Image Classification

Objectif : entraîner un CNN pour une classification binaire et analyser l'impact du nombre de convolutions.

```
In [20]: import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense, Dropout
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.callbacks import EarlyStopping, ModelCheckpoint, Callback
import os
import time
import GPUtil
import psutil
```

```
In [21]: IMG_SIZE = (150, 150)
BATCH_SIZE = 32
EPOCHS = 20
```

```
In [22]: train_datagen = ImageDataGenerator(
    rescale=1./255,
    zoom_range=0.2,
    shear_range=0.2,
    horizontal_flip=True
)

validation_datagen = ImageDataGenerator(rescale=1./255)

train_generator = train_datagen.flow_from_directory(
    "../dataset/seg_train",
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode="categorical" # MULTICLASSE
)

validation_generator = validation_datagen.flow_from_directory(
    "../dataset/seg_test",
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode="categorical" # MULTICLASSE
)
```

Found 14034 images belonging to 6 classes.

Found 3000 images belonging to 6 classes.

```
In [23]: def build_cnn(nb_conv):
    model = Sequential()

    # 1ère convolution
    model.add(Conv2D(32, (3,3), activation='relu', input_shape=(150,150,3)))
    model.add(MaxPooling2D((2,2)))

    # 2ème convolution
```

```

model.add(Conv2D(32, (3,3), activation='relu'))
model.add(MaxPooling2D((2,2)))

# 3ème convolution OPTIONNELLE
if nb_conv == 3:
    model.add(Conv2D(64, (3,3), activation='relu'))
    model.add(MaxPooling2D((2,2)))

model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))           # régularisation pour éviter overfitting
model.add(Dense(6, activation='softmax')) # 6 classes pour Intel

model.compile(
    optimizer='adam',
    loss='categorical_crossentropy', # multiclass
    metrics=['accuracy']
)

return model

```

In [24]:

```

def get_cpu_ram():
    cpu_percent = psutil.cpu_percent(interval=1)
    ram = psutil.virtual_memory()
    ram_used_mb = ram.used / (1024 ** 2)
    return cpu_percent, ram_used_mb
def get_gpu_stats():

    try:
        gpus = GPUUtil.getGPUs()
        if not gpus:
            return None, None, None
        gpu = gpus[0]
        return gpu.load * 100, gpu.memoryUsed, gpu.memoryTotal
    except:
        return None, None, None

```

In [25]:

```

class PerformanceCallback(Callback):
    def on_epoch_begin(self, epoch, logs=None):
        self.start_time = time.time()

    def on_epoch_end(self, epoch, logs=None):
        cpu, ram = get_cpu_ram()
        gpu, vram_used, vram_total = get_gpu_stats()
        duration = time.time() - self.start_time

        msg = f" | CPU: {cpu:.1f}% | RAM: {ram:.0f} MB | Time: {duration:.1f}s"
        if gpu is not None:
            msg += f" | GPU: {gpu:.1f}% | VRAM: {vram_used}/{vram_total} MB"
        print(msg)

    def get_callbacks(nb_conv):
        ckpt_dir = f"checkpoints_cnn_{nb_conv}"
        os.makedirs(ckpt_dir, exist_ok=True)

        checkpoint = ModelCheckpoint(
            filepath=os.path.join(ckpt_dir, "weights_epoch_{epoch:02d}.h5"),
            monitor="val_accuracy",

```

```
        save_weights_only=True,
        save_best_only=True,
        verbose=1
    )

    early_stop = EarlyStopping(
        monitor="val_accuracy",
        patience=5,
        restore_best_weights=True,
        verbose=1
    )

    return checkpoint, early_stop, ckpt_dir
```

```
In [26]: model_2 = build_cnn(nb_conv=2)

checkpoint, early_stop, ckpt_dir = get_callbacks(2)

history_2 = model_2.fit(
    train_generator,
    steps_per_epoch=train_generator.samples // BATCH_SIZE,
    epochs=20,
    validation_data=validation_generator,
    validation_steps=validation_generator.samples // BATCH_SIZE,
    callbacks=[checkpoint, early_stop, PerformanceCallback()],
    verbose=1
)
```

```
Epoch 1/20
438/438 [=====] - ETA: 0s - loss: 1.1502 - accuracy: 0.5
572
Epoch 1: val_accuracy improved from -inf to 0.63474, saving model to checkpoints_
cnn_2\weights_epoch_01.h5
| CPU: 2.2% | RAM: 15761 MB | Time: 49.2s | GPU: 5.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 112ms/step - loss: 1.1502 - accuracy: 0.5572 - val_loss: 0.9365 - val_accuracy: 0.6347
Epoch 2/20
438/438 [=====] - ETA: 0s - loss: 0.9286 - accuracy: 0.6
520
Epoch 2: val_accuracy improved from 0.63474 to 0.70430, saving model to checkpoints_
cnn_2\weights_epoch_02.h5
| CPU: 3.6% | RAM: 15807 MB | Time: 48.8s | GPU: 9.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 111ms/step - loss: 0.9286 - accuracy: 0.6520 - val_loss: 0.7825 - val_accuracy: 0.7043
Epoch 3/20
438/438 [=====] - ETA: 0s - loss: 0.8284 - accuracy: 0.6
971
Epoch 3: val_accuracy improved from 0.70430 to 0.75907, saving model to checkpoints_
cnn_2\weights_epoch_03.h5
| CPU: 1.2% | RAM: 15846 MB | Time: 48.0s | GPU: 4.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 48s 110ms/step - loss: 0.8284 - accuracy: 0.6971 - val_loss: 0.6935 - val_accuracy: 0.7591
Epoch 4/20
438/438 [=====] - ETA: 0s - loss: 0.7674 - accuracy: 0.7
181
Epoch 4: val_accuracy did not improve from 0.75907
| CPU: 2.8% | RAM: 15813 MB | Time: 47.6s | GPU: 7.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 48s 109ms/step - loss: 0.7674 - accuracy: 0.7181 - val_loss: 0.7013 - val_accuracy: 0.7369
Epoch 5/20
438/438 [=====] - ETA: 0s - loss: 0.7004 - accuracy: 0.7
510
Epoch 5: val_accuracy improved from 0.75907 to 0.76882, saving model to checkpoints_
cnn_2\weights_epoch_05.h5
| CPU: 4.3% | RAM: 15607 MB | Time: 48.6s | GPU: 4.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 111ms/step - loss: 0.7004 - accuracy: 0.7510 - val_loss: 0.6346 - val_accuracy: 0.7688
Epoch 6/20
438/438 [=====] - ETA: 0s - loss: 0.6545 - accuracy: 0.7
675
Epoch 6: val_accuracy improved from 0.76882 to 0.80712, saving model to checkpoints_
cnn_2\weights_epoch_06.h5
| CPU: 3.4% | RAM: 15597 MB | Time: 48.8s | GPU: 5.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 111ms/step - loss: 0.6545 - accuracy: 0.7675 - val_loss: 0.5594 - val_accuracy: 0.8071
Epoch 7/20
438/438 [=====] - ETA: 0s - loss: 0.6261 - accuracy: 0.7
796
Epoch 7: val_accuracy did not improve from 0.80712
| CPU: 3.7% | RAM: 15626 MB | Time: 48.8s | GPU: 2.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 111ms/step - loss: 0.6261 - accuracy: 0.7796 - val_loss: 0.5756 - val_accuracy: 0.7913
Epoch 8/20
438/438 [=====] - ETA: 0s - loss: 0.6006 - accuracy: 0.7
893
Epoch 8: val_accuracy improved from 0.80712 to 0.82661, saving model to checkpoints_
cnn_2\weights_epoch_08.h5
| CPU: 2.4% | RAM: 15610 MB | Time: 48.5s | GPU: 2.0% | VRAM: 908.0/16303.0 MB
```

```
438/438 [=====] - 49s 111ms/step - loss: 0.6006 - accuracy: 0.7893 - val_loss: 0.5288 - val_accuracy: 0.8266
Epoch 9/20
438/438 [=====] - ETA: 0s - loss: 0.5795 - accuracy: 0.7972
Epoch 9: val_accuracy did not improve from 0.82661
| CPU: 1.8% | RAM: 15616 MB | Time: 48.8s | GPU: 1.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 111ms/step - loss: 0.5795 - accuracy: 0.7972 - val_loss: 0.5726 - val_accuracy: 0.8048
Epoch 10/20
438/438 [=====] - ETA: 0s - loss: 0.5519 - accuracy: 0.8035
Epoch 10: val_accuracy did not improve from 0.82661
| CPU: 1.9% | RAM: 15692 MB | Time: 48.6s | GPU: 2.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 111ms/step - loss: 0.5519 - accuracy: 0.8035 - val_loss: 0.5552 - val_accuracy: 0.8048
Epoch 11/20
438/438 [=====] - ETA: 0s - loss: 0.5320 - accuracy: 0.8133
Epoch 11: val_accuracy improved from 0.82661 to 0.82964, saving model to checkpoints_cnn_2\weights_epoch_11.h5
| CPU: 1.2% | RAM: 15640 MB | Time: 48.5s | GPU: 2.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 48s 111ms/step - loss: 0.5320 - accuracy: 0.8133 - val_loss: 0.5166 - val_accuracy: 0.8296
Epoch 12/20
438/438 [=====] - ETA: 0s - loss: 0.5234 - accuracy: 0.8157
Epoch 12: val_accuracy did not improve from 0.82964
| CPU: 2.5% | RAM: 15728 MB | Time: 48.5s | GPU: 2.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 111ms/step - loss: 0.5234 - accuracy: 0.8157 - val_loss: 0.4966 - val_accuracy: 0.8266
Epoch 13/20
438/438 [=====] - ETA: 0s - loss: 0.5053 - accuracy: 0.8210
Epoch 13: val_accuracy did not improve from 0.82964
| CPU: 3.1% | RAM: 15672 MB | Time: 48.6s | GPU: 5.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 111ms/step - loss: 0.5053 - accuracy: 0.8210 - val_loss: 0.5189 - val_accuracy: 0.8283
Epoch 14/20
438/438 [=====] - ETA: 0s - loss: 0.4957 - accuracy: 0.8231
Epoch 14: val_accuracy improved from 0.82964 to 0.83065, saving model to checkpoints_cnn_2\weights_epoch_14.h5
| CPU: 2.8% | RAM: 15707 MB | Time: 49.0s | GPU: 4.0% | VRAM: 908.0/16303.0 MB
438/438 [=====] - 49s 112ms/step - loss: 0.4957 - accuracy: 0.8231 - val_loss: 0.5127 - val_accuracy: 0.8306
Epoch 15/20
438/438 [=====] - ETA: 0s - loss: 0.4798 - accuracy: 0.8288
Epoch 15: val_accuracy did not improve from 0.83065
| CPU: 2.1% | RAM: 15672 MB | Time: 49.1s | GPU: 2.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 112ms/step - loss: 0.4798 - accuracy: 0.8288 - val_loss: 0.5483 - val_accuracy: 0.8196
Epoch 16/20
438/438 [=====] - ETA: 0s - loss: 0.4738 - accuracy: 0.8318
Epoch 16: val_accuracy did not improve from 0.83065
| CPU: 1.9% | RAM: 15740 MB | Time: 49.3s | GPU: 4.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 112ms/step - loss: 0.4738 - accuracy: 0.8318 - val_loss: 0.5332 - val_accuracy: 0.8135
```

```
Epoch 17/20
438/438 [=====] - ETA: 0s - loss: 0.4645 - accuracy: 0.8355
Epoch 17: val_accuracy improved from 0.83065 to 0.84341, saving model to checkpoints_cnn_2\weights_epoch_17.h5
| CPU: 2.9% | RAM: 15715 MB | Time: 49.2s | GPU: 2.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 112ms/step - loss: 0.4645 - accuracy: 0.8355 - val_loss: 0.4700 - val_accuracy: 0.8434
Epoch 18/20
438/438 [=====] - ETA: 0s - loss: 0.4445 - accuracy: 0.8409
Epoch 18: val_accuracy did not improve from 0.84341
| CPU: 3.8% | RAM: 15628 MB | Time: 49.0s | GPU: 3.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 49s 112ms/step - loss: 0.4445 - accuracy: 0.8409 - val_loss: 0.4839 - val_accuracy: 0.8397
Epoch 19/20
438/438 [=====] - ETA: 0s - loss: 0.4496 - accuracy: 0.8390
Epoch 19: val_accuracy improved from 0.84341 to 0.84677, saving model to checkpoints_cnn_2\weights_epoch_19.h5
| CPU: 2.0% | RAM: 15626 MB | Time: 49.9s | GPU: 2.0% | VRAM: 856.0/16303.0 MB
438/438 [=====] - 50s 114ms/step - loss: 0.4496 - accuracy: 0.8390 - val_loss: 0.4738 - val_accuracy: 0.8468
Epoch 20/20
438/438 [=====] - ETA: 0s - loss: 0.4330 - accuracy: 0.8442
Epoch 20: val_accuracy improved from 0.84677 to 0.85148, saving model to checkpoints_cnn_2\weights_epoch_20.h5
| CPU: 2.2% | RAM: 15672 MB | Time: 49.3s | GPU: 4.0% | VRAM: 883.0/16303.0 MB
438/438 [=====] - 49s 113ms/step - loss: 0.4330 - accuracy: 0.8442 - val_loss: 0.4574 - val_accuracy: 0.8515
```

```
In [ ]: %%sql
```

```
In [27]: model_3 = build_cnn(nb_conv=3)

checkpoint, early_stop, ckpt_dir = get_callbacks(3)

history_3 = model_3.fit(
    train_generator,
    steps_per_epoch=train_generator.samples // BATCH_SIZE,
    epochs=20,
    validation_data=validation_generator,
    validation_steps=validation_generator.samples // BATCH_SIZE,
    callbacks=[checkpoint, early_stop, PerformanceCallback()],
    verbose=1
)
```

Epoch 1/20  
438/438 [=====] - ETA: 0s - loss: 1.1305 - accuracy: 0.5  
575  
Epoch 1: val\_accuracy improved from -inf to 0.67977, saving model to checkpoints\_cnn\_3\weights\_epoch\_01.h5  
| CPU: 2.3% | RAM: 15695 MB | Time: 51.3s | GPU: 2.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 51s 117ms/step - loss: 1.1305 - accuracy: 0.5575 - val\_loss: 0.8409 - val\_accuracy: 0.6798  
Epoch 2/20  
438/438 [=====] - ETA: 0s - loss: 0.9041 - accuracy: 0.6  
563  
Epoch 2: val\_accuracy improved from 0.67977 to 0.75974, saving model to checkpoints\_cnn\_3\weights\_epoch\_02.h5  
| CPU: 2.6% | RAM: 15666 MB | Time: 52.0s | GPU: 2.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 52s 119ms/step - loss: 0.9041 - accuracy: 0.6563 - val\_loss: 0.6708 - val\_accuracy: 0.7597  
Epoch 3/20  
438/438 [=====] - ETA: 0s - loss: 0.7605 - accuracy: 0.7  
265  
Epoch 3: val\_accuracy improved from 0.75974 to 0.78293, saving model to checkpoints\_cnn\_3\weights\_epoch\_03.h5  
| CPU: 2.5% | RAM: 15652 MB | Time: 51.3s | GPU: 2.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 51s 117ms/step - loss: 0.7605 - accuracy: 0.7265 - val\_loss: 0.6015 - val\_accuracy: 0.7829  
Epoch 4/20  
438/438 [=====] - ETA: 0s - loss: 0.6685 - accuracy: 0.7  
590  
Epoch 4: val\_accuracy improved from 0.78293 to 0.80981, saving model to checkpoints\_cnn\_3\weights\_epoch\_04.h5  
| CPU: 2.4% | RAM: 15642 MB | Time: 50.9s | GPU: 4.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 51s 116ms/step - loss: 0.6685 - accuracy: 0.7590 - val\_loss: 0.5332 - val\_accuracy: 0.8098  
Epoch 5/20  
438/438 [=====] - ETA: 0s - loss: 0.6147 - accuracy: 0.7  
805  
Epoch 5: val\_accuracy improved from 0.80981 to 0.81586, saving model to checkpoints\_cnn\_3\weights\_epoch\_05.h5  
| CPU: 2.2% | RAM: 15678 MB | Time: 51.0s | GPU: 4.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 51s 116ms/step - loss: 0.6147 - accuracy: 0.7805 - val\_loss: 0.5376 - val\_accuracy: 0.8159  
Epoch 6/20  
438/438 [=====] - ETA: 0s - loss: 0.5599 - accuracy: 0.8  
008  
Epoch 6: val\_accuracy improved from 0.81586 to 0.84140, saving model to checkpoints\_cnn\_3\weights\_epoch\_06.h5  
| CPU: 1.7% | RAM: 15714 MB | Time: 51.7s | GPU: 2.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 52s 118ms/step - loss: 0.5599 - accuracy: 0.8008 - val\_loss: 0.4670 - val\_accuracy: 0.8414  
Epoch 7/20  
438/438 [=====] - ETA: 0s - loss: 0.5377 - accuracy: 0.8  
119  
Epoch 7: val\_accuracy improved from 0.84140 to 0.85013, saving model to checkpoints\_cnn\_3\weights\_epoch\_07.h5  
| CPU: 1.9% | RAM: 15726 MB | Time: 51.6s | GPU: 2.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 52s 118ms/step - loss: 0.5377 - accuracy: 0.8119 - val\_loss: 0.4576 - val\_accuracy: 0.8501  
Epoch 8/20  
438/438 [=====] - ETA: 0s - loss: 0.5085 - accuracy: 0.8  
200  
Epoch 8: val\_accuracy did not improve from 0.85013

```
| CPU: 5.8% | RAM: 15711 MB | Time: 51.3s | GPU: 4.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 51s 117ms/step - loss: 0.5085 - accuracy: 0.8200 - val_loss: 0.4614 - val_accuracy: 0.8454  
Epoch 9/20  
438/438 [=====] - ETA: 0s - loss: 0.4905 - accuracy: 0.8288  
Epoch 9: val_accuracy improved from 0.85013 to 0.85181, saving model to checkpoints_cnn_3\weights_epoch_09.h5  
| CPU: 2.1% | RAM: 15676 MB | Time: 50.6s | GPU: 4.0% | VRAM: 935.0/16303.0 MB  
438/438 [=====] - 51s 115ms/step - loss: 0.4905 - accuracy: 0.8288 - val_loss: 0.4358 - val_accuracy: 0.8518  
Epoch 10/20  
438/438 [=====] - ETA: 0s - loss: 0.4688 - accuracy: 0.8356  
Epoch 10: val_accuracy did not improve from 0.85181  
| CPU: 2.3% | RAM: 15717 MB | Time: 51.6s | GPU: 9.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 52s 118ms/step - loss: 0.4688 - accuracy: 0.8356 - val_loss: 0.4526 - val_accuracy: 0.8464  
Epoch 11/20  
438/438 [=====] - ETA: 0s - loss: 0.4521 - accuracy: 0.8410  
Epoch 11: val_accuracy did not improve from 0.85181  
| CPU: 2.4% | RAM: 16006 MB | Time: 52.3s | GPU: 3.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 52s 119ms/step - loss: 0.4521 - accuracy: 0.8410 - val_loss: 0.4533 - val_accuracy: 0.8384  
Epoch 12/20  
438/438 [=====] - ETA: 0s - loss: 0.4311 - accuracy: 0.8482  
Epoch 12: val_accuracy did not improve from 0.85181  
| CPU: 3.1% | RAM: 15954 MB | Time: 54.3s | GPU: 5.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 54s 124ms/step - loss: 0.4311 - accuracy: 0.8482 - val_loss: 0.4725 - val_accuracy: 0.8306  
Epoch 13/20  
438/438 [=====] - ETA: 0s - loss: 0.4209 - accuracy: 0.8515  
Epoch 13: val_accuracy improved from 0.85181 to 0.86022, saving model to checkpoints_cnn_3\weights_epoch_13.h5  
| CPU: 1.7% | RAM: 15930 MB | Time: 54.0s | GPU: 2.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 54s 123ms/step - loss: 0.4209 - accuracy: 0.8515 - val_loss: 0.4172 - val_accuracy: 0.8602  
Epoch 14/20  
438/438 [=====] - ETA: 0s - loss: 0.4001 - accuracy: 0.8594  
Epoch 14: val_accuracy did not improve from 0.86022  
| CPU: 1.7% | RAM: 15666 MB | Time: 54.3s | GPU: 3.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 54s 124ms/step - loss: 0.4001 - accuracy: 0.8594 - val_loss: 0.4368 - val_accuracy: 0.8511  
Epoch 15/20  
438/438 [=====] - ETA: 0s - loss: 0.3937 - accuracy: 0.8594  
Epoch 15: val_accuracy improved from 0.86022 to 0.86358, saving model to checkpoints_cnn_3\weights_epoch_15.h5  
| CPU: 2.4% | RAM: 15769 MB | Time: 53.7s | GPU: 1.0% | VRAM: 883.0/16303.0 MB  
438/438 [=====] - 54s 122ms/step - loss: 0.3937 - accuracy: 0.8594 - val_loss: 0.4002 - val_accuracy: 0.8636  
Epoch 16/20  
438/438 [=====] - ETA: 0s - loss: 0.3774 - accuracy: 0.8662  
Epoch 16: val_accuracy did not improve from 0.86358  
| CPU: 1.9% | RAM: 15707 MB | Time: 53.7s | GPU: 5.0% | VRAM: 883.0/16303.0 MB
```

```
438/438 [=====] - 54s 123ms/step - loss: 0.3774 - accuracy: 0.8662 - val_loss: 0.4448 - val_accuracy: 0.8636
Epoch 17/20
438/438 [=====] - ETA: 0s - loss: 0.3771 - accuracy: 0.8664
Epoch 17: val_accuracy improved from 0.86358 to 0.86593, saving model to checkpoints_cnn_3\weights_epoch_17.h5
| CPU: 6.4% | RAM: 15705 MB | Time: 53.7s | GPU: 2.0% | VRAM: 883.0/16303.0 MB
438/438 [=====] - 54s 123ms/step - loss: 0.3771 - accuracy: 0.8664 - val_loss: 0.3979 - val_accuracy: 0.8659
Epoch 18/20
438/438 [=====] - ETA: 0s - loss: 0.3650 - accuracy: 0.8685
Epoch 18: val_accuracy did not improve from 0.86593
| CPU: 1.5% | RAM: 15666 MB | Time: 53.5s | GPU: 3.0% | VRAM: 883.0/16303.0 MB
438/438 [=====] - 54s 122ms/step - loss: 0.3650 - accuracy: 0.8685 - val_loss: 0.4513 - val_accuracy: 0.8632
Epoch 19/20
438/438 [=====] - ETA: 0s - loss: 0.3375 - accuracy: 0.8779
Epoch 19: val_accuracy improved from 0.86593 to 0.86862, saving model to checkpoints_cnn_3\weights_epoch_19.h5
| CPU: 3.2% | RAM: 15662 MB | Time: 53.5s | GPU: 3.0% | VRAM: 883.0/16303.0 MB
438/438 [=====] - 53s 122ms/step - loss: 0.3375 - accuracy: 0.8779 - val_loss: 0.4229 - val_accuracy: 0.8686
Epoch 20/20
438/438 [=====] - ETA: 0s - loss: 0.3389 - accuracy: 0.8767
Epoch 20: val_accuracy did not improve from 0.86862
| CPU: 2.1% | RAM: 15650 MB | Time: 53.8s | GPU: 3.0% | VRAM: 883.0/16303.0 MB
438/438 [=====] - 54s 123ms/step - loss: 0.3389 - accuracy: 0.8767 - val_loss: 0.4119 - val_accuracy: 0.8659
```

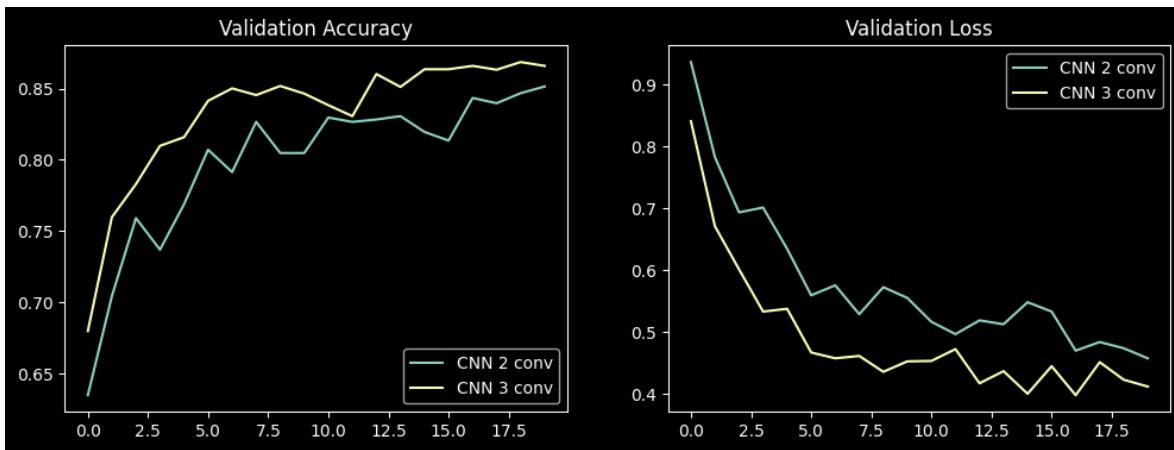
In [28]: `import matplotlib.pyplot as plt`

```
plt.figure(figsize=(12,4))

plt.subplot(1,2,1)
plt.plot(history_2.history["val_accuracy"], label="CNN 2 conv")
plt.plot(history_3.history["val_accuracy"], label="CNN 3 conv")
plt.title("Validation Accuracy")
plt.legend()

plt.subplot(1,2,2)
plt.plot(history_2.history["val_loss"], label="CNN 2 conv")
plt.plot(history_3.history["val_loss"], label="CNN 3 conv")
plt.title("Validation Loss")
plt.legend()

plt.show()
```



## Comparaison CNN 2 convolutions vs CNN 3 convolutions

L'entraînement des deux architectures montre que l'ajout d'une troisième couche de convolution améliore les performances du modèle, tout en conservant un entraînement stable sur ce nouveau dataset. Les tendances observées sont cohérentes avec celles obtenues précédemment sur le dataset Dogs & Cats.

CNN à 2 convolutions :

- Précision maximale sur l'ensemble de validation : 85,15 % (epoch 20)
- Perte de validation minimale : 0,4574
- Meilleur modèle atteint en fin d'entraînement, sans déclenchement de l'early stopping

CNN à 3 convolutions :

- Précision maximale sur l'ensemble de validation : 86,86 % (epoch 19)
- Perte de validation minimale : 0,4229
- Meilleur modèle atteint à l'epoch 19, avec une légère dégradation ensuite

Le graphique comparatif montre que le CNN à 3 convolutions converge plus rapidement et maintient une précision de validation supérieure à celle du CNN à 2 convolutions sur la majorité des epochs. La perte de validation plus faible observée pour le modèle à 3 convolutions traduit une meilleure capacité de généralisation, sans apparition d'overfitting significatif.

Ainsi, ce second jeu de données confirme que l'augmentation modérée de la profondeur d'un CNN améliore la performance globale du modèle, comme observé précédemment sur Dogs & Cats.

Lors de ces entraînements CNN, l'utilisation des ressources reste globalement faible et stable : le CPU tourne surtout autour de 1–4 % (avec quelques pointes vers 6 %), la RAM reste proche de 15,6–15,9 Go, et la VRAM reste < 1 Go (environ 856–935 Mo).

L'utilisation GPU est modérée (souvent 2–5 %, avec un pic à 9 % sur le 3 conv), tandis que le temps par epoch est d'environ 49 s (2 conv) contre 51–54 s (3 conv), ce qui est cohérent avec un modèle plus profond.