

dog-vs-cat-classification

November 2, 2025

1 Dog vs Cat Classification

1.0.1 Importing the required libraries

```
[1]: import os, shutil, random
from glob import glob
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from PIL import Image
import pandas as pd

import tensorflow as tf
from tensorflow.keras import layers, models, optimizers, regularizers, Input, Model
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.applications import MobileNetV2, EfficientNetB0
from tensorflow.keras.applications.mobilenet_v2 import preprocess_input as mb_preprocess
from tensorflow.keras.applications.efficientnet import preprocess_input as eff_preprocess
from tensorflow.keras.callbacks import EarlyStopping, ReduceLROnPlateau, ModelCheckpoint

from sklearn.model_selection import train_test_split
from sklearn.metrics import roc_auc_score, classification_report, confusion_matrix
import json
sns.set(style="whitegrid")
```

2025-11-02 09:24:45.762541: E
external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:477] Unable to register cuFFT factory: Attempting to register factory for plugin cuFFT when one has already been registered
WARNING: All log messages before absl::InitializeLog() is called are written to STDERR
E0000 00:00:1762075486.155276 19 cuda_dnn.cc:8310] Unable to register cuDNN factory: Attempting to register factory for plugin cuDNN when one has already

```
been registered
E0000 00:00:1762075486.313211      19 cuda_blas.cc:1418] Unable to register
cuBLAS factory: Attempting to register factory for plugin cuBLAS when one has
already been registered
```

```
[2]: print(tf.__version__)
```

```
2.18.0
```

1.0.2 Configuration

```
[3]: SEED = 42
IMG_SIZE = 224
BATCH_SIZE = 32
LIMIT_PER_CLASS = None ## For testing before complete run
EPOCHS_CUSTOM = 50
EPOCHS_TL_INIT = 50
EPOCHS_TL_FINE = 50
FINE_TUNE_LAST_N = 20
INPUT_DIR = "/kaggle/input/dog-vs-cat"
DATA_DIR = "/kaggle/working/data"

os.makedirs(DATA_DIR, exist_ok=True)
tf.random.set_seed(SEED)
np.random.seed(SEED)
```

1.0.3 Data loading and labelling

```
[4]: files = sorted(glob(os.path.join(INPUT_DIR, "train", "*.jpg")))
print("Raw files found:", len(files))

pairs = []
for f in files:
    fname = os.path.basename(f).lower()
    if "cat" in fname:
        pairs.append((f, "cat"))
    elif "dog" in fname:
        pairs.append((f, "dog"))

if LIMIT_PER_CLASS:
    cats = [p for p in pairs if p[1] == "cat"][:LIMIT_PER_CLASS]
    dogs = [p for p in pairs if p[1] == "dog"][:LIMIT_PER_CLASS]
    pairs = cats + dogs
    print(f"LIMIT_PER_CLASS used: {LIMIT_PER_CLASS} per class -> total ↴{len(pairs)}")

labels = [p[1] for p in pairs]
print("Total images used:", len(pairs))
```

```
Raw files found: 25000
Total images used: 25000
```

1.0.4 Data splitting

```
[5]: train_pairs, test_pairs = train_test_split(pairs, test_size=0.2, u
    ↪stratify=labels, random_state=SEED)
train_pairs, val_pairs = train_test_split(train_pairs, test_size=0.125, u
    ↪stratify=[p[1] for p in train_pairs], random_state=SEED)

for split in ["train", "val", "test"]:
    for cls in ["cat", "dog"]:
        os.makedirs(os.path.join(DATA_DIR, split, cls), exist_ok=True)

def copy_pairs(p_list, split):
    for src, cls in p_list:
        dst = os.path.join(DATA_DIR, split, cls, os.path.basename(src))
        if not os.path.exists(dst):
            shutil.copy(src, dst)

copy_pairs(train_pairs, "train")
copy_pairs(val_pairs, "val")
copy_pairs(test_pairs, "test")
print("Data prepared at:", DATA_DIR)
```

```
Data prepared at: /kaggle/working/data
```

1.0.5 Checking class balance

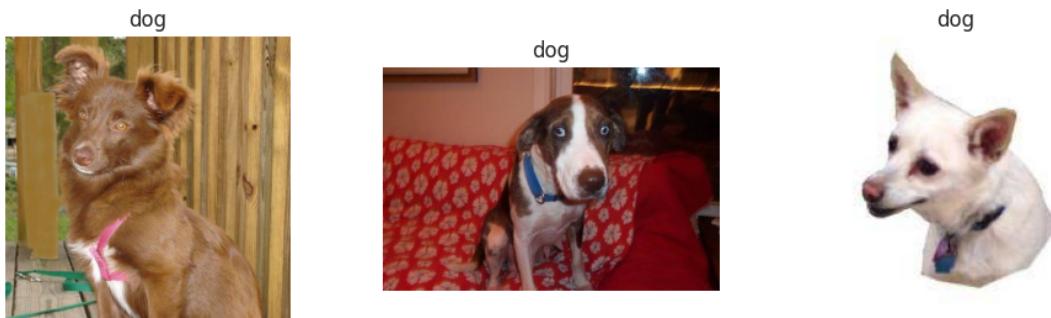
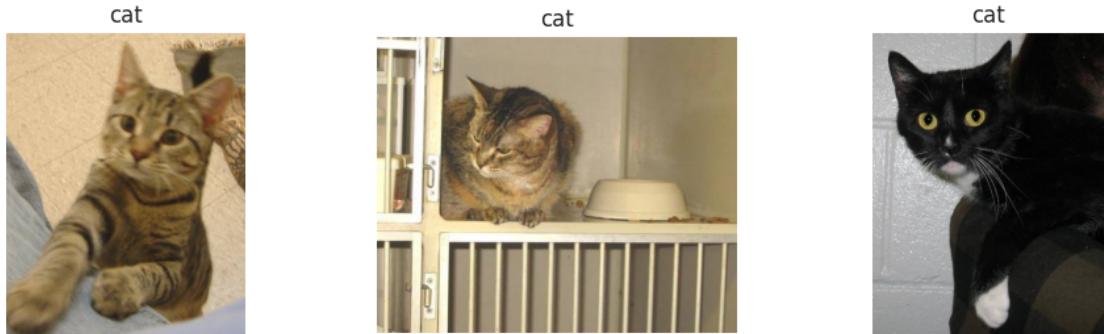
```
[6]: num_cats = sum(1 for _,lbl in pairs if lbl=='cat')
num_dogs = sum(1 for _,lbl in pairs if lbl=='dog')
print(f"Cats: {num_cats}, Dogs: {num_dogs}")
```

```
Cats: 12500, Dogs: 12500
```

1.0.6 Displaying random images from the dataset

```
[7]: def show_random(class_name, n=3):
    class_files = [p[0] for p in pairs if p[1]==class_name]
    sampled = random.sample(class_files, min(n, len(class_files)))
    plt.figure(figsize=(12,3))
    for i,f in enumerate(sampled):
        img = Image.open(f)
        plt.subplot(1, n, i+1)
        plt.imshow(img)
        plt.title(class_name)
        plt.axis('off')
    plt.show()
```

```
show_random("cat")
show_random("dog")
```



1.0.7 Data preparation

```
[8]: def create_generators_for_custom(rescale=1./255):
    train_datagen = ImageDataGenerator(rescale=rescale,
                                         rotation_range=20, width_shift_range=0.
                                         ↪15,
                                         height_shift_range=0.15, shear_range=0.
                                         ↪12,
                                         zoom_range=0.15, horizontal_flip=True, ↪
                                         ↪fill_mode='nearest')
    val_datagen = ImageDataGenerator(rescale=rescale)
    train_gen = train_datagen.flow_from_directory(os.path.
                                         ↪join(DATA_DIR, "train"),
                                         ↪target_size=(IMG_SIZE,IMG_SIZE),
                                         ↪batch_size=BATCH_SIZE, ↪
                                         ↪class_mode='binary',
```

```

        shuffle=True, seed=SEED)
val_gen = val_datagen.flow_from_directory(os.path.join(DATA_DIR, "val"),
                                         target_size=(IMG_SIZE,IMG_SIZE),
                                         batch_size=BATCH_SIZE,□
↪class_mode='binary',
                                         shuffle=False)
test_gen = val_datagen.flow_from_directory(os.path.join(DATA_DIR, "test"),
                                         target_size=(IMG_SIZE,IMG_SIZE),
                                         batch_size=BATCH_SIZE,□
↪class_mode='binary',
                                         shuffle=False)
return train_gen, val_gen, test_gen

def create_generators_for_tl(preprocess_fn):
    train_datagen = ImageDataGenerator(preprocessing_function=preprocess_fn,
                                         rotation_range=20, width_shift_range=0.
↪15,
                                         height_shift_range=0.15, shear_range=0.
↪12,
                                         zoom_range=0.15, horizontal_flip=True,□
↪fill_mode='nearest')
    val_datagen = ImageDataGenerator(preprocessing_function=preprocess_fn)
    train_gen = train_datagen.flow_from_directory(os.path.
↪join(DATA_DIR, "train"),
                                               □
↪target_size=(IMG_SIZE,IMG_SIZE),
                                         batch_size=BATCH_SIZE,□
↪class_mode='binary',
                                         shuffle=True, seed=SEED)
    val_gen = val_datagen.flow_from_directory(os.path.join(DATA_DIR, "val"),
                                         target_size=(IMG_SIZE,IMG_SIZE),
                                         batch_size=BATCH_SIZE,□
↪class_mode='binary',
                                         shuffle=False)
    test_gen = val_datagen.flow_from_directory(os.path.join(DATA_DIR, "test"),
                                         target_size=(IMG_SIZE,IMG_SIZE),
                                         batch_size=BATCH_SIZE,□
↪class_mode='binary',
                                         shuffle=False)
return train_gen, val_gen, test_gen

train_gen_custom, val_gen_custom, test_gen_custom =□
↪create_generators_for_custom()
train_gen_mb, val_gen_mb, test_gen_mb = create_generators_for_tl(mb_preprocess)
train_gen_eff, val_gen_eff, test_gen_eff =□
↪create_generators_for_tl(eff_preprocess)

```

```
Found 17500 images belonging to 2 classes.  
Found 2500 images belonging to 2 classes.  
Found 5000 images belonging to 2 classes.  
Found 17500 images belonging to 2 classes.  
Found 2500 images belonging to 2 classes.  
Found 5000 images belonging to 2 classes.  
Found 17500 images belonging to 2 classes.  
Found 2500 images belonging to 2 classes.  
Found 5000 images belonging to 2 classes.
```

1.0.8 Defining callbacks

```
[9]: def get_callbacks(name, monitor='val_auc'):  
    weights_filepath = f"best_{name}.weights.h5"      # must end with '.weights.h5'  
    es = EarlyStopping(monitor=monitor, patience=5, restore_best_weights=True, □  
    ↵verbose=1, mode='max')  
    rlr = ReduceLROnPlateau(monitor=monitor, factor=0.5, patience=3, □  
    ↵min_lr=1e-6, verbose=1, mode='max')  
    ckpt = ModelCheckpoint(weights_filepath, monitor=monitor, □  
    ↵save_best_only=True, save_weights_only=True, mode='max', verbose=1)  
    return [es, rlr, ckpt]
```

1.0.9 Building CNN models

```
[10]: def build_custom_cnn(input_shape=(IMG_SIZE,IMG_SIZE,3)):  
    model = models.Sequential([  
        layers.  
        ↵Conv2D(16,3,padding='same',activation='relu',input_shape=input_shape,kernel_regularizer=regularizers.  
        ↵l2(1e-4)),  
        layers.BatchNormalization(),  
        layers.  
        ↵Conv2D(16,3,padding='same',activation='relu',kernel_regularizer=regularizers.  
        ↵l2(1e-4)),  
        layers.BatchNormalization(),  
        layers.MaxPooling2D(), layers.Dropout(0.2),  
  
        layers.  
        ↵Conv2D(32,3,padding='same',activation='relu',kernel_regularizer=regularizers.  
        ↵l2(1e-4)),  
        layers.BatchNormalization(),  
        layers.  
        ↵Conv2D(32,3,padding='same',activation='relu',kernel_regularizer=regularizers.  
        ↵l2(1e-4)),  
        layers.BatchNormalization(),  
        layers.MaxPooling2D(), layers.Dropout(0.3),
```

```

        layers.
    ↵Conv2D(64,3,padding='same',activation='relu',kernel_regularizer=regularizers.
    ↵l2(1e-4)),
        layers.BatchNormalization(),
        layers.
    ↵Conv2D(64,3,padding='same',activation='relu',kernel_regularizer=regularizers.
    ↵l2(1e-4)),
        layers.BatchNormalization(),
        layers.MaxPooling2D(), layers.Dropout(0.3),

        layers.
    ↵Conv2D(128,3,padding='same',activation='relu',kernel_regularizer=regularizers.
    ↵l2(1e-4)),
        layers.BatchNormalization(),
        layers.
    ↵Conv2D(128,3,padding='same',activation='relu',kernel_regularizer=regularizers.
    ↵l2(1e-4)),
        layers.BatchNormalization(),
        layers.MaxPooling2D(), layers.Dropout(0.4),

        layers.Flatten(),
        layers.Dense(256,activation='relu',kernel_regularizer=regularizers.
    ↵l2(1e-4)),
        layers.BatchNormalization(),
        layers.Dropout(0.5),
        layers.Dense(1, activation='sigmoid')
    ))
model.compile(optimizer=optimizers.Adam(1e-3),
              loss='binary_crossentropy',
              metrics=['accuracy', tf.keras.metrics.AUC(name='auc')])
return model

def build_mobilenetv2(input_shape=(IMG_SIZE,IMG_SIZE,3)):
    base = MobileNetV2(weights='imagenet', include_top=False,□
    ↵input_shape=input_shape)
    base.trainable = False
    inputs = Input(shape=input_shape)
    x = base(inputs, training=False)
    x = layers.GlobalAveragePooling2D()(x)
    x = layers.Dropout(0.2)(x)
    outputs = layers.Dense(1, activation='sigmoid')(x)
    model = Model(inputs, outputs, name="MobileNetV2_Classifier")
    model.compile(optimizer=optimizers.Adam(1e-3), loss='binary_crossentropy',
                  metrics=['accuracy', tf.keras.metrics.AUC(name='auc')])
    return model, base

```

```

def build_efficientnetb0(input_shape=(IMG_SIZE,IMG_SIZE,3)):
    base = EfficientNetB0(weights='imagenet', include_top=False,_
    ↪input_shape=input_shape)
    base.trainable = False
    inputs = Input(shape=input_shape)
    x = base(inputs, training=False)
    x = layers.GlobalAveragePooling2D()(x)
    x = layers.Dropout(0.2)(x)
    outputs = layers.Dense(1, activation='sigmoid')(x)
    model = Model(inputs, outputs, name="EfficientNetB0_Classifier")
    model.compile(optimizer=optimizers.Adam(1e-3), loss='binary_crossentropy',
                  metrics=['accuracy', tf.keras.metrics.AUC(name='auc')])
    return model, base

```

1.0.10 Training the models

```

[11]: from sklearn.metrics import roc_auc_score

def train_one(build_fn, name, train_gen, val_gen, test_gen,
              epochs_init, epochs_fine=None, fine_tune_layers=FINE_TUNE_LAST_N):

    ret = build_fn()
    if isinstance(ret, tuple) and len(ret)==2:
        model, base = ret
    else:
        model = ret
        base = None

    callbacks = get_callbacks(name)

    # initial training
    hist_init = model.fit(train_gen, validation_data=val_gen,
                          epochs=epochs_init, callbacks=callbacks,
                          steps_per_epoch=len(train_gen),
                          validation_steps=len(val_gen))
    hist = hist_init

    # fine-tuning for pretrained models
    if epochs_fine and base is not None:
        print(f"[{name}] Fine-tuning: unfreezing last {fine_tune_layers} layers."
        ↪..")
        base.trainable = True
        total = len(base.layers)
        freeze_until = max(0, total - fine_tune_layers)
        for i, layer in enumerate(base.layers):
            layer.trainable = False if i < freeze_until else True

```

```

        model.compile(optimizer=optimizers.Adam(1e-5),  

        ↪loss='binary_crossentropy',  

                    metrics=['accuracy', tf.keras.metrics.AUC(name='auc')])  
  

        hist_fine = model.fit(train_gen, validation_data=val_gen,  

                                epochs=epochs_fine, callbacks=callbacks,  

                                steps_per_epoch=len(train_gen),  

                                validation_steps=len(val_gen))  
  

        # merge histories  

        combined = {}  

        for k in set(list(hist_init.history.keys()) + list(hist_fine.history.  

        ↪keys())):  

            combined[k] = hist_init.history.get(k, []) + hist_fine.history.  

        ↪get(k, [])  

            class SimpleHistory:  

                def __init__(self, h): self.history = h  

                hist = SimpleHistory(combined)  

            elif epochs_fine and base is None:  

                print(f"[{name}] Fine-tune requested but no base model; skipping.")  
  

        # evaluating the models  

        preds = model.predict(test_gen, verbose=0)  

        y_prob = preds.reshape(-1)  

        y_pred = (y_prob > 0.5).astype(int)  

        y_true = test_gen.classes  

        acc = np.mean(y_pred == y_true)  

        auc = roc_auc_score(y_true, y_prob)  
  

        return model, hist, acc, auc, y_pred, y_true

```

1.0.11 Custom CNN

```
[12]: tf.keras.backend.clear_session()  

custom_model, h_custom, acc_custom, auc_custom, pred_custom, true_custom =  

    ↪train_one(  

        build_custom_cnn, "custom", train_gen_custom, val_gen_custom,  

    ↪test_gen_custom,  

        epochs_init=EPOCHS_CUSTOM, epochs_fine=None  

    )  

print("Custom CNN -> Acc: %.4f, AUC: %.4f" % (acc_custom, auc_custom))
```

/usr/local/lib/python3.11/dist-
packages/keras/src/layers/convolutional/base_conv.py:107: UserWarning: Do not
pass an `input_shape`/`input_dim` argument to a layer. When using Sequential
models, prefer using an `Input(shape)` object as the first layer in the model
instead.

```

super().__init__(activity_regularizer=activity_regularizer, **kwargs)
I0000 00:00:1762075769.291334      19 gpu_device.cc:2022] Created device
/job:localhost/replica:0/task:0/device:GPU:0 with 13942 MB memory: -> device:
0, name: Tesla T4, pci bus id: 0000:00:04.0, compute capability: 7.5
I0000 00:00:1762075769.292045      19 gpu_device.cc:2022] Created device
/job:localhost/replica:0/task:0/device:GPU:1 with 13942 MB memory: -> device:
1, name: Tesla T4, pci bus id: 0000:00:05.0, compute capability: 7.5
/usr/local/lib/python3.11/dist-
packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121:
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()

Epoch 1/50

WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
I0000 00:00:1762075781.713594      128 service.cc:148] XLA service 0x7ca7fc002350
initialized for platform CUDA (this does not guarantee that XLA will be used).
Devices:
I0000 00:00:1762075781.715097      128 service.cc:156] StreamExecutor device
(0): Tesla T4, Compute Capability 7.5
I0000 00:00:1762075781.715123      128 service.cc:156] StreamExecutor device
(1): Tesla T4, Compute Capability 7.5
I0000 00:00:1762075782.778345      128 cuda_dnn.cc:529] Loaded cuDNN version
90300

1/547              3:45:24 25s/step -
accuracy: 0.4062 - auc: 0.4434 - loss: 1.2189

I0000 00:00:1762075796.505947      128 device_compiler.h:188] Compiled cluster
using XLA! This line is logged at most once for the lifetime of the process.

547/547            0s 350ms/step -
accuracy: 0.5921 - auc: 0.6261 - loss: 0.8803
Epoch 1: val_auc improved from -inf to 0.73688, saving model to
best_custom.weights.h5
547/547            225s 366ms/step -
accuracy: 0.5921 - auc: 0.6262 - loss: 0.8802 - val_accuracy: 0.6468 - val_auc:
0.7369 - val_loss: 0.7457 - learning_rate: 0.0010
Epoch 2/50

547/547            0s 335ms/step -
accuracy: 0.6952 - auc: 0.7660 - loss: 0.7164
Epoch 2: val_auc improved from 0.73688 to 0.85393, saving model to
best_custom.weights.h5
547/547            187s 342ms/step -
accuracy: 0.6953 - auc: 0.7660 - loss: 0.7164 - val_accuracy: 0.7640 - val_auc:
0.8539 - val_loss: 0.6102 - learning_rate: 0.0010

```

```
Epoch 3/50
547/547           0s 327ms/step -
accuracy: 0.7443 - auc: 0.8206 - loss: 0.6495
Epoch 3: val_auc improved from 0.85393 to 0.87674, saving model to
best_custom.weights.h5
547/547           183s 335ms/step -
accuracy: 0.7443 - auc: 0.8206 - loss: 0.6495 - val_accuracy: 0.7504 - val_auc:
0.8767 - val_loss: 0.6372 - learning_rate: 0.0010
Epoch 4/50
547/547           0s 336ms/step -
accuracy: 0.7864 - auc: 0.8645 - loss: 0.5904
Epoch 4: val_auc improved from 0.87674 to 0.90109, saving model to
best_custom.weights.h5
547/547           188s 343ms/step -
accuracy: 0.7864 - auc: 0.8646 - loss: 0.5904 - val_accuracy: 0.7136 - val_auc:
0.9011 - val_loss: 0.7746 - learning_rate: 0.0010
Epoch 5/50
547/547           0s 330ms/step -
accuracy: 0.8150 - auc: 0.8937 - loss: 0.5583
Epoch 5: val_auc improved from 0.90109 to 0.91810, saving model to
best_custom.weights.h5
547/547           185s 337ms/step -
accuracy: 0.8150 - auc: 0.8937 - loss: 0.5582 - val_accuracy: 0.8220 - val_auc:
0.9181 - val_loss: 0.5450 - learning_rate: 0.0010
Epoch 6/50
547/547           0s 327ms/step -
accuracy: 0.8433 - auc: 0.9172 - loss: 0.5337
Epoch 6: val_auc improved from 0.91810 to 0.95218, saving model to
best_custom.weights.h5
547/547           183s 334ms/step -
accuracy: 0.8433 - auc: 0.9172 - loss: 0.5337 - val_accuracy: 0.8548 - val_auc:
0.9522 - val_loss: 0.5148 - learning_rate: 0.0010
Epoch 7/50
547/547           0s 327ms/step -
accuracy: 0.8655 - auc: 0.9407 - loss: 0.5037
Epoch 7: val_auc improved from 0.95218 to 0.95922, saving model to
best_custom.weights.h5
547/547           183s 335ms/step -
accuracy: 0.8655 - auc: 0.9407 - loss: 0.5037 - val_accuracy: 0.8764 - val_auc:
0.9592 - val_loss: 0.4706 - learning_rate: 0.0010
Epoch 8/50
547/547           0s 327ms/step -
accuracy: 0.8817 - auc: 0.9533 - loss: 0.4761
Epoch 8: val_auc did not improve from 0.95922
547/547           183s 335ms/step -
accuracy: 0.8817 - auc: 0.9533 - loss: 0.4761 - val_accuracy: 0.8220 - val_auc:
0.9480 - val_loss: 0.6253 - learning_rate: 0.0010
Epoch 9/50
```

```
547/547          0s 325ms/step -
accuracy: 0.8959 - auc: 0.9594 - loss: 0.4714
Epoch 9: val_auc did not improve from 0.95922
547/547          181s 332ms/step -
accuracy: 0.8959 - auc: 0.9594 - loss: 0.4714 - val_accuracy: 0.8676 - val_auc:
0.9524 - val_loss: 0.5061 - learning_rate: 0.0010
Epoch 10/50
547/547          0s 328ms/step -
accuracy: 0.8977 - auc: 0.9631 - loss: 0.4732
Epoch 10: val_auc improved from 0.95922 to 0.98342, saving model to
best_custom.weights.h5
547/547          184s 336ms/step -
accuracy: 0.8977 - auc: 0.9631 - loss: 0.4732 - val_accuracy: 0.9224 - val_auc:
0.9834 - val_loss: 0.4130 - learning_rate: 0.0010
Epoch 11/50
547/547          0s 332ms/step -
accuracy: 0.9005 - auc: 0.9674 - loss: 0.4640
Epoch 11: val_auc did not improve from 0.98342
547/547          186s 339ms/step -
accuracy: 0.9005 - auc: 0.9674 - loss: 0.4640 - val_accuracy: 0.9204 - val_auc:
0.9829 - val_loss: 0.4187 - learning_rate: 0.0010
Epoch 12/50
547/547          0s 328ms/step -
accuracy: 0.9064 - auc: 0.9700 - loss: 0.4638
Epoch 12: val_auc did not improve from 0.98342
547/547          183s 335ms/step -
accuracy: 0.9064 - auc: 0.9700 - loss: 0.4638 - val_accuracy: 0.9216 - val_auc:
0.9832 - val_loss: 0.4292 - learning_rate: 0.0010
Epoch 13/50
547/547          0s 326ms/step -
accuracy: 0.9114 - auc: 0.9710 - loss: 0.4578
Epoch 13: val_auc improved from 0.98342 to 0.98427, saving model to
best_custom.weights.h5
547/547          183s 334ms/step -
accuracy: 0.9114 - auc: 0.9710 - loss: 0.4578 - val_accuracy: 0.9304 - val_auc:
0.9843 - val_loss: 0.4139 - learning_rate: 0.0010
Epoch 14/50
547/547          0s 335ms/step -
accuracy: 0.9164 - auc: 0.9738 - loss: 0.4498
Epoch 14: val_auc did not improve from 0.98427
547/547          188s 343ms/step -
accuracy: 0.9164 - auc: 0.9738 - loss: 0.4498 - val_accuracy: 0.9228 - val_auc:
0.9806 - val_loss: 0.4267 - learning_rate: 0.0010
Epoch 15/50
547/547          0s 329ms/step -
accuracy: 0.9164 - auc: 0.9741 - loss: 0.4502
Epoch 15: val_auc improved from 0.98427 to 0.98591, saving model to
best_custom.weights.h5
```

```
547/547           184s 337ms/step -
accuracy: 0.9164 - auc: 0.9741 - loss: 0.4502 - val_accuracy: 0.9224 - val_auc:
0.9859 - val_loss: 0.4288 - learning_rate: 0.0010
Epoch 16/50
547/547           0s 332ms/step -
accuracy: 0.9193 - auc: 0.9755 - loss: 0.4531
Epoch 16: val_auc improved from 0.98591 to 0.98902, saving model to
best_custom.weights.h5
547/547           186s 339ms/step -
accuracy: 0.9193 - auc: 0.9755 - loss: 0.4531 - val_accuracy: 0.9468 - val_auc:
0.9890 - val_loss: 0.3865 - learning_rate: 0.0010
Epoch 17/50
547/547           0s 328ms/step -
accuracy: 0.9179 - auc: 0.9766 - loss: 0.4436
Epoch 17: val_auc improved from 0.98902 to 0.98905, saving model to
best_custom.weights.h5
547/547           183s 335ms/step -
accuracy: 0.9179 - auc: 0.9766 - loss: 0.4436 - val_accuracy: 0.9432 - val_auc:
0.9891 - val_loss: 0.3907 - learning_rate: 0.0010
Epoch 18/50
547/547           0s 330ms/step -
accuracy: 0.9258 - auc: 0.9778 - loss: 0.4362
Epoch 18: val_auc improved from 0.98905 to 0.99145, saving model to
best_custom.weights.h5
547/547           185s 337ms/step -
accuracy: 0.9258 - auc: 0.9778 - loss: 0.4362 - val_accuracy: 0.9548 - val_auc:
0.9914 - val_loss: 0.3608 - learning_rate: 0.0010
Epoch 19/50
547/547           0s 328ms/step -
accuracy: 0.9276 - auc: 0.9783 - loss: 0.4242
Epoch 19: val_auc did not improve from 0.99145
547/547           183s 335ms/step -
accuracy: 0.9276 - auc: 0.9783 - loss: 0.4242 - val_accuracy: 0.9316 - val_auc:
0.9859 - val_loss: 0.3925 - learning_rate: 0.0010
Epoch 20/50
547/547           0s 327ms/step -
accuracy: 0.9270 - auc: 0.9783 - loss: 0.4301
Epoch 20: val_auc did not improve from 0.99145
547/547           183s 334ms/step -
accuracy: 0.9270 - auc: 0.9783 - loss: 0.4301 - val_accuracy: 0.9252 - val_auc:
0.9861 - val_loss: 0.4035 - learning_rate: 0.0010
Epoch 21/50
547/547           0s 333ms/step -
accuracy: 0.9242 - auc: 0.9789 - loss: 0.4206
Epoch 21: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 21: val_auc did not improve from 0.99145
547/547           186s 340ms/step -
```

```
accuracy: 0.9242 - auc: 0.9789 - loss: 0.4206 - val_accuracy: 0.9420 - val_auc:  
0.9877 - val_loss: 0.3908 - learning_rate: 0.0010  
Epoch 22/50  
547/547          0s 327ms/step -  
accuracy: 0.9358 - auc: 0.9836 - loss: 0.3889  
Epoch 22: val_auc improved from 0.99145 to 0.99402, saving model to  
best_custom.weights.h5  
547/547          183s 335ms/step -  
accuracy: 0.9358 - auc: 0.9836 - loss: 0.3888 - val_accuracy: 0.9524 - val_auc:  
0.9940 - val_loss: 0.3036 - learning_rate: 5.0000e-04  
Epoch 23/50  
547/547          0s 329ms/step -  
accuracy: 0.9381 - auc: 0.9864 - loss: 0.3396  
Epoch 23: val_auc improved from 0.99402 to 0.99445, saving model to  
best_custom.weights.h5  
547/547          184s 337ms/step -  
accuracy: 0.9381 - auc: 0.9864 - loss: 0.3396 - val_accuracy: 0.9608 - val_auc:  
0.9945 - val_loss: 0.2758 - learning_rate: 5.0000e-04  
Epoch 24/50  
547/547          0s 329ms/step -  
accuracy: 0.9393 - auc: 0.9858 - loss: 0.3294  
Epoch 24: val_auc improved from 0.99445 to 0.99493, saving model to  
best_custom.weights.h5  
547/547          184s 337ms/step -  
accuracy: 0.9393 - auc: 0.9858 - loss: 0.3294 - val_accuracy: 0.9644 - val_auc:  
0.9949 - val_loss: 0.2692 - learning_rate: 5.0000e-04  
Epoch 25/50  
547/547          0s 333ms/step -  
accuracy: 0.9426 - auc: 0.9870 - loss: 0.3131  
Epoch 25: val_auc did not improve from 0.99493  
547/547          186s 339ms/step -  
accuracy: 0.9426 - auc: 0.9870 - loss: 0.3131 - val_accuracy: 0.9576 - val_auc:  
0.9941 - val_loss: 0.2632 - learning_rate: 5.0000e-04  
Epoch 26/50  
547/547          0s 330ms/step -  
accuracy: 0.9449 - auc: 0.9874 - loss: 0.3062  
Epoch 26: val_auc improved from 0.99493 to 0.99505, saving model to  
best_custom.weights.h5  
547/547          185s 338ms/step -  
accuracy: 0.9449 - auc: 0.9874 - loss: 0.3063 - val_accuracy: 0.9584 - val_auc:  
0.9951 - val_loss: 0.2592 - learning_rate: 5.0000e-04  
Epoch 27/50  
547/547          0s 333ms/step -  
accuracy: 0.9476 - auc: 0.9891 - loss: 0.2942  
Epoch 27: val_auc improved from 0.99505 to 0.99554, saving model to  
best_custom.weights.h5  
547/547          186s 340ms/step -  
accuracy: 0.9476 - auc: 0.9891 - loss: 0.2942 - val_accuracy: 0.9652 - val_auc:
```

```
0.9955 - val_loss: 0.2463 - learning_rate: 5.0000e-04
Epoch 28/50
547/547          0s 330ms/step -
accuracy: 0.9430 - auc: 0.9872 - loss: 0.3017
Epoch 28: val_auc did not improve from 0.99554
547/547          185s 338ms/step -
accuracy: 0.9430 - auc: 0.9872 - loss: 0.3017 - val_accuracy: 0.9592 - val_auc:
0.9942 - val_loss: 0.2626 - learning_rate: 5.0000e-04
Epoch 29/50
547/547          0s 326ms/step -
accuracy: 0.9461 - auc: 0.9883 - loss: 0.2925
Epoch 29: val_auc improved from 0.99554 to 0.99585, saving model to
best_custom.weights.h5
547/547          182s 333ms/step -
accuracy: 0.9461 - auc: 0.9883 - loss: 0.2925 - val_accuracy: 0.9668 - val_auc:
0.9958 - val_loss: 0.2353 - learning_rate: 5.0000e-04
Epoch 30/50
547/547          0s 327ms/step -
accuracy: 0.9441 - auc: 0.9878 - loss: 0.2939
Epoch 30: val_auc did not improve from 0.99585
547/547          182s 333ms/step -
accuracy: 0.9441 - auc: 0.9878 - loss: 0.2939 - val_accuracy: 0.9552 - val_auc:
0.9936 - val_loss: 0.2786 - learning_rate: 5.0000e-04
Epoch 31/50
547/547          0s 328ms/step -
accuracy: 0.9481 - auc: 0.9883 - loss: 0.2869
Epoch 31: val_auc did not improve from 0.99585
547/547          183s 334ms/step -
accuracy: 0.9481 - auc: 0.9883 - loss: 0.2869 - val_accuracy: 0.9632 - val_auc:
0.9951 - val_loss: 0.2431 - learning_rate: 5.0000e-04
Epoch 32/50
547/547          0s 329ms/step -
accuracy: 0.9476 - auc: 0.9884 - loss: 0.2847
Epoch 32: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.

Epoch 32: val_auc did not improve from 0.99585
547/547          184s 336ms/step -
accuracy: 0.9476 - auc: 0.9884 - loss: 0.2847 - val_accuracy: 0.9580 - val_auc:
0.9953 - val_loss: 0.2372 - learning_rate: 5.0000e-04
Epoch 33/50
547/547          0s 324ms/step -
accuracy: 0.9513 - auc: 0.9906 - loss: 0.2647
Epoch 33: val_auc improved from 0.99585 to 0.99625, saving model to
best_custom.weights.h5
547/547          182s 332ms/step -
accuracy: 0.9513 - auc: 0.9906 - loss: 0.2647 - val_accuracy: 0.9660 - val_auc:
0.9963 - val_loss: 0.2214 - learning_rate: 2.5000e-04
Epoch 34/50
```

```
547/547          0s 330ms/step -
accuracy: 0.9542 - auc: 0.9909 - loss: 0.2522
Epoch 34: val_auc did not improve from 0.99625
547/547          184s 336ms/step -
accuracy: 0.9542 - auc: 0.9909 - loss: 0.2522 - val_accuracy: 0.9692 - val_auc:
0.9961 - val_loss: 0.2058 - learning_rate: 2.5000e-04
Epoch 35/50
547/547          0s 328ms/step -
accuracy: 0.9521 - auc: 0.9914 - loss: 0.2436
Epoch 35: val_auc improved from 0.99625 to 0.99690, saving model to
best_custom.weights.h5
547/547          184s 336ms/step -
accuracy: 0.9521 - auc: 0.9914 - loss: 0.2436 - val_accuracy: 0.9696 - val_auc:
0.9969 - val_loss: 0.1985 - learning_rate: 2.5000e-04
Epoch 36/50
547/547          0s 329ms/step -
accuracy: 0.9575 - auc: 0.9927 - loss: 0.2276
Epoch 36: val_auc did not improve from 0.99690
547/547          184s 336ms/step -
accuracy: 0.9575 - auc: 0.9927 - loss: 0.2276 - val_accuracy: 0.9680 - val_auc:
0.9966 - val_loss: 0.1974 - learning_rate: 2.5000e-04
Epoch 37/50
547/547          0s 328ms/step -
accuracy: 0.9614 - auc: 0.9929 - loss: 0.2208
Epoch 37: val_auc improved from 0.99690 to 0.99714, saving model to
best_custom.weights.h5
547/547          184s 335ms/step -
accuracy: 0.9614 - auc: 0.9929 - loss: 0.2209 - val_accuracy: 0.9688 - val_auc:
0.9971 - val_loss: 0.1880 - learning_rate: 2.5000e-04
Epoch 38/50
547/547          0s 330ms/step -
accuracy: 0.9589 - auc: 0.9921 - loss: 0.2252
Epoch 38: val_auc did not improve from 0.99714
547/547          184s 337ms/step -
accuracy: 0.9589 - auc: 0.9921 - loss: 0.2252 - val_accuracy: 0.9664 - val_auc:
0.9962 - val_loss: 0.1958 - learning_rate: 2.5000e-04
Epoch 39/50
547/547          0s 330ms/step -
accuracy: 0.9541 - auc: 0.9912 - loss: 0.2313
Epoch 39: val_auc did not improve from 0.99714
547/547          184s 337ms/step -
accuracy: 0.9541 - auc: 0.9912 - loss: 0.2313 - val_accuracy: 0.9684 - val_auc:
0.9952 - val_loss: 0.2013 - learning_rate: 2.5000e-04
Epoch 40/50
547/547          0s 328ms/step -
accuracy: 0.9578 - auc: 0.9921 - loss: 0.2224
Epoch 40: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.
```

```

Epoch 40: val_auc did not improve from 0.99714
547/547           183s 334ms/step -
accuracy: 0.9578 - auc: 0.9921 - loss: 0.2224 - val_accuracy: 0.9708 - val_auc:
0.9959 - val_loss: 0.1917 - learning_rate: 2.5000e-04
Epoch 41/50
547/547           0s 329ms/step -
accuracy: 0.9593 - auc: 0.9915 - loss: 0.2232
Epoch 41: val_auc did not improve from 0.99714
547/547           184s 336ms/step -
accuracy: 0.9594 - auc: 0.9915 - loss: 0.2232 - val_accuracy: 0.9728 - val_auc:
0.9969 - val_loss: 0.1749 - learning_rate: 1.2500e-04
Epoch 42/50
547/547           0s 327ms/step -
accuracy: 0.9611 - auc: 0.9932 - loss: 0.2085
Epoch 42: val_auc did not improve from 0.99714
547/547           183s 335ms/step -
accuracy: 0.9611 - auc: 0.9932 - loss: 0.2085 - val_accuracy: 0.9728 - val_auc:
0.9968 - val_loss: 0.1743 - learning_rate: 1.2500e-04
Epoch 42: early stopping
Restoring model weights from the end of the best epoch: 37.
Custom CNN -> Acc: 0.9692, AUC: 0.9961

```

1.0.12 Mobilenet

```
[13]: tf.keras.backend.clear_session()
mb_model, h_mb, acc_mb, auc_mb, pred_mb, true_mb = train_one(
    build_mobilenetv2, "mobilenet", train_gen_mb, val_gen_mb, test_gen_mb,
    epochs_init=EPOCHS_TL_INIT, epochs_fine=EPOCHS_TL_FINE, ↴
    ↴fine_tune_layers=FINE_TUNE_LAST_N
)
print("MobileNetV2 -> Acc: %.4f, AUC: %.4f" % (acc_mb, auc_mb))
```

```

Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/mobilenet_v2/mobilenet_v2_weights_tf_dim_ordering_tf_kernels_1.0_224_no_top.h5
9406464/9406464          0s
0us/step

/usr/local/lib/python3.11/dist-
packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121:
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()

Epoch 1/50
547/547           0s 340ms/step -
accuracy: 0.9326 - auc: 0.9776 - loss: 0.1651

```

```
Epoch 1: val_auc improved from -inf to 0.99861, saving model to  
best_mobilenet.weights.h5  
547/547          208s 361ms/step -  
accuracy: 0.9327 - auc: 0.9776 - loss: 0.1650 - val_accuracy: 0.9800 - val_auc:  
0.9986 - val_loss: 0.0512 - learning_rate: 0.0010  
Epoch 2/50  
547/547          0s 325ms/step -  
accuracy: 0.9763 - auc: 0.9973 - loss: 0.0617  
Epoch 2: val_auc improved from 0.99861 to 0.99883, saving model to  
best_mobilenet.weights.h5  
547/547          184s 336ms/step -  
accuracy: 0.9763 - auc: 0.9973 - loss: 0.0617 - val_accuracy: 0.9824 - val_auc:  
0.9988 - val_loss: 0.0487 - learning_rate: 0.0010  
Epoch 3/50  
547/547          0s 331ms/step -  
accuracy: 0.9817 - auc: 0.9981 - loss: 0.0505  
Epoch 3: val_auc improved from 0.99883 to 0.99925, saving model to  
best_mobilenet.weights.h5  
547/547          186s 339ms/step -  
accuracy: 0.9817 - auc: 0.9981 - loss: 0.0505 - val_accuracy: 0.9840 - val_auc:  
0.9993 - val_loss: 0.0370 - learning_rate: 0.0010  
Epoch 4/50  
547/547          0s 325ms/step -  
accuracy: 0.9833 - auc: 0.9981 - loss: 0.0489  
Epoch 4: val_auc did not improve from 0.99925  
547/547          182s 333ms/step -  
accuracy: 0.9833 - auc: 0.9981 - loss: 0.0489 - val_accuracy: 0.9836 - val_auc:  
0.9992 - val_loss: 0.0386 - learning_rate: 0.0010  
Epoch 5/50  
547/547          0s 327ms/step -  
accuracy: 0.9792 - auc: 0.9979 - loss: 0.0524  
Epoch 5: val_auc did not improve from 0.99925  
547/547          183s 334ms/step -  
accuracy: 0.9792 - auc: 0.9979 - loss: 0.0524 - val_accuracy: 0.9836 - val_auc:  
0.9992 - val_loss: 0.0414 - learning_rate: 0.0010  
Epoch 6/50  
547/547          0s 325ms/step -  
accuracy: 0.9833 - auc: 0.9983 - loss: 0.0478  
Epoch 6: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.  
  
Epoch 6: val_auc did not improve from 0.99925  
547/547          182s 332ms/step -  
accuracy: 0.9833 - auc: 0.9983 - loss: 0.0478 - val_accuracy: 0.9832 - val_auc:  
0.9992 - val_loss: 0.0423 - learning_rate: 0.0010  
Epoch 7/50  
547/547          0s 324ms/step -  
accuracy: 0.9827 - auc: 0.9975 - loss: 0.0518  
Epoch 7: val_auc did not improve from 0.99925
```

```
547/547           181s 331ms/step -
accuracy: 0.9827 - auc: 0.9975 - loss: 0.0518 - val_accuracy: 0.9816 - val_auc:
0.9991 - val_loss: 0.0464 - learning_rate: 5.0000e-04
Epoch 8/50
547/547           0s 325ms/step -
accuracy: 0.9825 - auc: 0.9985 - loss: 0.0458
Epoch 8: val_auc improved from 0.99925 to 0.99929, saving model to
best_mobilenet.weights.h5
547/547           182s 333ms/step -
accuracy: 0.9825 - auc: 0.9985 - loss: 0.0458 - val_accuracy: 0.9840 - val_auc:
0.9993 - val_loss: 0.0371 - learning_rate: 5.0000e-04
Epoch 9/50
547/547           0s 326ms/step -
accuracy: 0.9818 - auc: 0.9981 - loss: 0.0471
Epoch 9: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.

Epoch 9: val_auc did not improve from 0.99929
547/547           182s 333ms/step -
accuracy: 0.9818 - auc: 0.9981 - loss: 0.0471 - val_accuracy: 0.9840 - val_auc:
0.9992 - val_loss: 0.0394 - learning_rate: 5.0000e-04
Epoch 10/50
547/547           0s 326ms/step -
accuracy: 0.9828 - auc: 0.9980 - loss: 0.0452
Epoch 10: val_auc did not improve from 0.99929
547/547           182s 333ms/step -
accuracy: 0.9828 - auc: 0.9980 - loss: 0.0452 - val_accuracy: 0.9840 - val_auc:
0.9992 - val_loss: 0.0396 - learning_rate: 2.5000e-04
Epoch 11/50
547/547           0s 326ms/step -
accuracy: 0.9842 - auc: 0.9988 - loss: 0.0401
Epoch 11: val_auc did not improve from 0.99929
547/547           183s 334ms/step -
accuracy: 0.9842 - auc: 0.9988 - loss: 0.0401 - val_accuracy: 0.9840 - val_auc:
0.9993 - val_loss: 0.0392 - learning_rate: 2.5000e-04
Epoch 12/50
547/547           0s 324ms/step -
accuracy: 0.9845 - auc: 0.9982 - loss: 0.0426
Epoch 12: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.

Epoch 12: val_auc did not improve from 0.99929
547/547           181s 332ms/step -
accuracy: 0.9845 - auc: 0.9982 - loss: 0.0426 - val_accuracy: 0.9844 - val_auc:
0.9993 - val_loss: 0.0384 - learning_rate: 2.5000e-04
Epoch 13/50
547/547           0s 324ms/step -
accuracy: 0.9808 - auc: 0.9978 - loss: 0.0504
Epoch 13: val_auc did not improve from 0.99929
547/547           181s 331ms/step -
```

```
accuracy: 0.9808 - auc: 0.9978 - loss: 0.0504 - val_accuracy: 0.9840 - val_auc:  
0.9993 - val_loss: 0.0390 - learning_rate: 1.2500e-04  
Epoch 13: early stopping  
Restoring model weights from the end of the best epoch: 8.  
[mobilenet] Fine-tuning: unfreezing last 20 layers...  
Epoch 1/50  
547/547          0s 333ms/step -  
accuracy: 0.9409 - auc: 0.9908 - loss: 0.1609  
Epoch 1: val_auc did not improve from 0.99929  
547/547          207s 349ms/step -  
accuracy: 0.9409 - auc: 0.9908 - loss: 0.1608 - val_accuracy: 0.9736 - val_auc:  
0.9978 - val_loss: 0.0786 - learning_rate: 1.0000e-05  
Epoch 2/50  
547/547          0s 327ms/step -  
accuracy: 0.9732 - auc: 0.9966 - loss: 0.0689  
Epoch 2: val_auc improved from 0.99929 to 0.99930, saving model to  
best_mobilenet.weights.h5  
547/547          183s 335ms/step -  
accuracy: 0.9732 - auc: 0.9966 - loss: 0.0689 - val_accuracy: 0.9812 - val_auc:  
0.9993 - val_loss: 0.0512 - learning_rate: 1.0000e-05  
Epoch 3/50  
547/547          0s 327ms/step -  
accuracy: 0.9739 - auc: 0.9964 - loss: 0.0693  
Epoch 3: val_auc improved from 0.99930 to 0.99931, saving model to  
best_mobilenet.weights.h5  
547/547          183s 335ms/step -  
accuracy: 0.9739 - auc: 0.9964 - loss: 0.0693 - val_accuracy: 0.9820 - val_auc:  
0.9993 - val_loss: 0.0451 - learning_rate: 1.0000e-05  
Epoch 4/50  
547/547          0s 326ms/step -  
accuracy: 0.9766 - auc: 0.9975 - loss: 0.0599  
Epoch 4: val_auc improved from 0.99931 to 0.99936, saving model to  
best_mobilenet.weights.h5  
547/547          183s 334ms/step -  
accuracy: 0.9766 - auc: 0.9975 - loss: 0.0599 - val_accuracy: 0.9844 - val_auc:  
0.9994 - val_loss: 0.0370 - learning_rate: 1.0000e-05  
Epoch 5/50  
547/547          0s 329ms/step -  
accuracy: 0.9802 - auc: 0.9984 - loss: 0.0503  
Epoch 5: val_auc improved from 0.99936 to 0.99940, saving model to  
best_mobilenet.weights.h5  
547/547          185s 338ms/step -  
accuracy: 0.9802 - auc: 0.9984 - loss: 0.0503 - val_accuracy: 0.9872 - val_auc:  
0.9994 - val_loss: 0.0339 - learning_rate: 1.0000e-05  
Epoch 6/50  
547/547          0s 325ms/step -  
accuracy: 0.9784 - auc: 0.9976 - loss: 0.0553  
Epoch 6: val_auc did not improve from 0.99940
```

```
547/547           182s 333ms/step -
accuracy: 0.9784 - auc: 0.9976 - loss: 0.0553 - val_accuracy: 0.9856 - val_auc:
0.9990 - val_loss: 0.0339 - learning_rate: 1.0000e-05
Epoch 7/50
547/547           0s 327ms/step -
accuracy: 0.9808 - auc: 0.9980 - loss: 0.0511
Epoch 7: val_auc improved from 0.99940 to 0.99940, saving model to
best_mobilenet.weights.h5
547/547           183s 335ms/step -
accuracy: 0.9808 - auc: 0.9980 - loss: 0.0511 - val_accuracy: 0.9864 - val_auc:
0.9994 - val_loss: 0.0359 - learning_rate: 1.0000e-05
Epoch 8/50
547/547           0s 327ms/step -
accuracy: 0.9836 - auc: 0.9985 - loss: 0.0444
Epoch 8: ReduceLROnPlateau reducing learning rate to 4.999999873689376e-06.

Epoch 8: val_auc did not improve from 0.99940
547/547           183s 334ms/step -
accuracy: 0.9836 - auc: 0.9985 - loss: 0.0444 - val_accuracy: 0.9872 - val_auc:
0.9994 - val_loss: 0.0360 - learning_rate: 1.0000e-05
Epoch 9/50
547/547           0s 328ms/step -
accuracy: 0.9844 - auc: 0.9988 - loss: 0.0401
Epoch 9: val_auc improved from 0.99940 to 0.99941, saving model to
best_mobilenet.weights.h5
547/547           184s 336ms/step -
accuracy: 0.9844 - auc: 0.9988 - loss: 0.0401 - val_accuracy: 0.9872 - val_auc:
0.9994 - val_loss: 0.0342 - learning_rate: 5.0000e-06
Epoch 10/50
547/547           0s 326ms/step -
accuracy: 0.9822 - auc: 0.9985 - loss: 0.0460
Epoch 10: val_auc improved from 0.99941 to 0.99942, saving model to
best_mobilenet.weights.h5
547/547           183s 334ms/step -
accuracy: 0.9822 - auc: 0.9985 - loss: 0.0459 - val_accuracy: 0.9868 - val_auc:
0.9994 - val_loss: 0.0336 - learning_rate: 5.0000e-06
Epoch 11/50
547/547           0s 327ms/step -
accuracy: 0.9873 - auc: 0.9989 - loss: 0.0371
Epoch 11: ReduceLROnPlateau reducing learning rate to 2.499999936844688e-06.

Epoch 11: val_auc improved from 0.99942 to 0.99943, saving model to
best_mobilenet.weights.h5
547/547           184s 336ms/step -
accuracy: 0.9873 - auc: 0.9989 - loss: 0.0371 - val_accuracy: 0.9860 - val_auc:
0.9994 - val_loss: 0.0332 - learning_rate: 5.0000e-06
Epoch 12/50
547/547           0s 333ms/step -
```

```
accuracy: 0.9880 - auc: 0.9990 - loss: 0.0359
Epoch 12: val_auc did not improve from 0.99943
547/547          186s 341ms/step -
accuracy: 0.9880 - auc: 0.9990 - loss: 0.0359 - val_accuracy: 0.9860 - val_auc:
0.9994 - val_loss: 0.0329 - learning_rate: 2.5000e-06
Epoch 13/50
547/547          0s 327ms/step -
accuracy: 0.9862 - auc: 0.9990 - loss: 0.0366
Epoch 13: val_auc improved from 0.99943 to 0.99944, saving model to
best_mobilenet.weights.h5
547/547          184s 336ms/step -
accuracy: 0.9862 - auc: 0.9990 - loss: 0.0366 - val_accuracy: 0.9868 - val_auc:
0.9994 - val_loss: 0.0317 - learning_rate: 2.5000e-06
Epoch 14/50
547/547          0s 328ms/step -
accuracy: 0.9856 - auc: 0.9989 - loss: 0.0372
Epoch 14: ReduceLROnPlateau reducing learning rate to 1.249999968422344e-06.

Epoch 14: val_auc did not improve from 0.99944
547/547          184s 335ms/step -
accuracy: 0.9856 - auc: 0.9989 - loss: 0.0372 - val_accuracy: 0.9876 - val_auc:
0.9994 - val_loss: 0.0313 - learning_rate: 2.5000e-06
Epoch 15/50
547/547          0s 327ms/step -
accuracy: 0.9857 - auc: 0.9988 - loss: 0.0384
Epoch 15: val_auc did not improve from 0.99944
547/547          183s 335ms/step -
accuracy: 0.9857 - auc: 0.9988 - loss: 0.0384 - val_accuracy: 0.9876 - val_auc:
0.9994 - val_loss: 0.0312 - learning_rate: 1.2500e-06
Epoch 16/50
547/547          0s 330ms/step -
accuracy: 0.9890 - auc: 0.9992 - loss: 0.0315
Epoch 16: val_auc did not improve from 0.99944
547/547          185s 338ms/step -
accuracy: 0.9890 - auc: 0.9992 - loss: 0.0315 - val_accuracy: 0.9860 - val_auc:
0.9994 - val_loss: 0.0318 - learning_rate: 1.2500e-06
Epoch 17/50
547/547          0s 333ms/step -
accuracy: 0.9892 - auc: 0.9992 - loss: 0.0313
Epoch 17: ReduceLROnPlateau reducing learning rate to 1e-06.

Epoch 17: val_auc did not improve from 0.99944
547/547          187s 341ms/step -
accuracy: 0.9892 - auc: 0.9992 - loss: 0.0313 - val_accuracy: 0.9864 - val_auc:
0.9994 - val_loss: 0.0318 - learning_rate: 1.2500e-06
Epoch 18/50
547/547          0s 329ms/step -
accuracy: 0.9851 - auc: 0.9988 - loss: 0.0393
```

```

Epoch 18: val_auc did not improve from 0.99944
547/547           184s 337ms/step -
accuracy: 0.9851 - auc: 0.9988 - loss: 0.0393 - val_accuracy: 0.9860 - val_auc:
0.9994 - val_loss: 0.0321 - learning_rate: 1.0000e-06
Epoch 18: early stopping
Restoring model weights from the end of the best epoch: 13.
MobileNetV2 -> Acc: 0.9874, AUC: 0.9994

```

1.0.13 Efficientnet

```
[14]: tf.keras.backend.clear_session()
eff_model, h_eff, acc_eff, auc_eff, pred_eff, true_eff = train_one(
    build_efficientnetb0, "efficientnet", train_gen_eff, val_gen_eff, □
    ↪test_gen_eff,
    epochs_init=EPOCHS_TL_INIT, epochs_fine=EPOCHS_TL_FINE, □
    ↪fine_tune_layers=FINE_TUNE_LAST_N
)
print("EfficientNetB0 -> Acc: %.4f, AUC: %.4f" % (acc_eff, auc_eff))
```

```

Downloading data from https://storage.googleapis.com/keras-
applications/efficientnetb0_notop.h5
16705208/16705208          0s
0us/step

/usr/local/lib/python3.11/dist-
packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121:
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()

Epoch 1/50
547/547           0s 334ms/step -
accuracy: 0.9398 - auc: 0.9809 - loss: 0.1778
Epoch 1: val_auc improved from -inf to 0.99956, saving model to
best_efficientnet.weights.h5
547/547           221s 362ms/step -
accuracy: 0.9398 - auc: 0.9809 - loss: 0.1776 - val_accuracy: 0.9900 - val_auc:
0.9996 - val_loss: 0.0324 - learning_rate: 0.0010
Epoch 2/50
547/547           0s 319ms/step -
accuracy: 0.9859 - auc: 0.9984 - loss: 0.0457
Epoch 2: val_auc improved from 0.99956 to 0.99972, saving model to
best_efficientnet.weights.h5
547/547           179s 327ms/step -
accuracy: 0.9859 - auc: 0.9984 - loss: 0.0457 - val_accuracy: 0.9912 - val_auc:
0.9997 - val_loss: 0.0249 - learning_rate: 0.0010
Epoch 3/50

```

```

547/547          0s 323ms/step -
accuracy: 0.9866 - auc: 0.9986 - loss: 0.0407
Epoch 3: val_auc improved from 0.99972 to 0.99973, saving model to
best_efficientnet.weights.h5
547/547          182s 332ms/step -
accuracy: 0.9866 - auc: 0.9986 - loss: 0.0407 - val_accuracy: 0.9916 - val_auc:
0.9997 - val_loss: 0.0239 - learning_rate: 0.0010
Epoch 4/50
547/547          0s 319ms/step -
accuracy: 0.9876 - auc: 0.9988 - loss: 0.0366
Epoch 4: val_auc did not improve from 0.99973
547/547          178s 326ms/step -
accuracy: 0.9876 - auc: 0.9988 - loss: 0.0366 - val_accuracy: 0.9928 - val_auc:
0.9997 - val_loss: 0.0237 - learning_rate: 0.0010
Epoch 5/50
547/547          0s 318ms/step -
accuracy: 0.9883 - auc: 0.9989 - loss: 0.0344
Epoch 5: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 5: val_auc did not improve from 0.99973
547/547          178s 325ms/step -
accuracy: 0.9883 - auc: 0.9989 - loss: 0.0344 - val_accuracy: 0.9912 - val_auc:
0.9997 - val_loss: 0.0241 - learning_rate: 0.0010
Epoch 6/50
547/547          0s 318ms/step -
accuracy: 0.9883 - auc: 0.9991 - loss: 0.0313
Epoch 6: val_auc did not improve from 0.99973
547/547          178s 325ms/step -
accuracy: 0.9883 - auc: 0.9991 - loss: 0.0313 - val_accuracy: 0.9916 - val_auc:
0.9997 - val_loss: 0.0228 - learning_rate: 5.0000e-04
Epoch 7/50
547/547          0s 319ms/step -
accuracy: 0.9882 - auc: 0.9992 - loss: 0.0314
Epoch 7: val_auc did not improve from 0.99973
547/547          178s 326ms/step -
accuracy: 0.9882 - auc: 0.9992 - loss: 0.0314 - val_accuracy: 0.9920 - val_auc:
0.9997 - val_loss: 0.0225 - learning_rate: 5.0000e-04
Epoch 8/50
547/547          0s 318ms/step -
accuracy: 0.9893 - auc: 0.9994 - loss: 0.0285
Epoch 8: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.

Epoch 8: val_auc did not improve from 0.99973
547/547          178s 325ms/step -
accuracy: 0.9893 - auc: 0.9994 - loss: 0.0285 - val_accuracy: 0.9912 - val_auc:
0.9997 - val_loss: 0.0232 - learning_rate: 5.0000e-04
Epoch 8: early stopping
Restoring model weights from the end of the best epoch: 3.

```

```
[efficientnet] Fine-tuning: unfreezing last 20 layers...
Epoch 1/50
547/547          0s 338ms/step -
accuracy: 0.9705 - auc: 0.9960 - loss: 0.0936
Epoch 1: val_auc did not improve from 0.99973
547/547          228s 365ms/step -
accuracy: 0.9705 - auc: 0.9960 - loss: 0.0936 - val_accuracy: 0.9888 - val_auc:
0.9995 - val_loss: 0.0305 - learning_rate: 1.0000e-05
Epoch 2/50
547/547          0s 321ms/step -
accuracy: 0.9780 - auc: 0.9980 - loss: 0.0585
Epoch 2: val_auc did not improve from 0.99973
547/547          179s 328ms/step -
accuracy: 0.9780 - auc: 0.9980 - loss: 0.0585 - val_accuracy: 0.9888 - val_auc:
0.9996 - val_loss: 0.0264 - learning_rate: 1.0000e-05
Epoch 3/50
547/547          0s 321ms/step -
accuracy: 0.9809 - auc: 0.9979 - loss: 0.0541
Epoch 3: val_auc did not improve from 0.99973
547/547          180s 329ms/step -
accuracy: 0.9809 - auc: 0.9979 - loss: 0.0541 - val_accuracy: 0.9892 - val_auc:
0.9997 - val_loss: 0.0246 - learning_rate: 1.0000e-05
Epoch 4/50
547/547          0s 323ms/step -
accuracy: 0.9815 - auc: 0.9982 - loss: 0.0487
Epoch 4: val_auc did not improve from 0.99973
547/547          181s 330ms/step -
accuracy: 0.9815 - auc: 0.9982 - loss: 0.0487 - val_accuracy: 0.9892 - val_auc:
0.9997 - val_loss: 0.0239 - learning_rate: 1.0000e-05
Epoch 5/50
547/547          0s 322ms/step -
accuracy: 0.9841 - auc: 0.9989 - loss: 0.0406
Epoch 5: ReduceLROnPlateau reducing learning rate to 4.999999873689376e-06.

Epoch 5: val_auc did not improve from 0.99973
547/547          180s 329ms/step -
accuracy: 0.9841 - auc: 0.9989 - loss: 0.0406 - val_accuracy: 0.9888 - val_auc:
0.9997 - val_loss: 0.0233 - learning_rate: 1.0000e-05
Epoch 6/50
547/547          0s 323ms/step -
accuracy: 0.9858 - auc: 0.9987 - loss: 0.0404
Epoch 6: val_auc did not improve from 0.99973
547/547          180s 330ms/step -
accuracy: 0.9858 - auc: 0.9987 - loss: 0.0404 - val_accuracy: 0.9888 - val_auc:
0.9997 - val_loss: 0.0229 - learning_rate: 5.0000e-06
Epoch 7/50
547/547          0s 321ms/step -
accuracy: 0.9869 - auc: 0.9992 - loss: 0.0354
```

```
Epoch 7: val_auc improved from 0.99973 to 0.99974, saving model to
best_efficientnet.weights.h5
547/547          180s 329ms/step -
accuracy: 0.9869 - auc: 0.9992 - loss: 0.0354 - val_accuracy: 0.9888 - val_auc:
0.9997 - val_loss: 0.0222 - learning_rate: 5.0000e-06
Epoch 8/50
547/547          0s 323ms/step -
accuracy: 0.9833 - auc: 0.9983 - loss: 0.0443
Epoch 8: ReduceLROnPlateau reducing learning rate to 2.49999936844688e-06.

Epoch 8: val_auc did not improve from 0.99974
547/547          180s 329ms/step -
accuracy: 0.9833 - auc: 0.9983 - loss: 0.0443 - val_accuracy: 0.9888 - val_auc:
0.9997 - val_loss: 0.0223 - learning_rate: 5.0000e-06
Epoch 9/50
547/547          0s 322ms/step -
accuracy: 0.9856 - auc: 0.9990 - loss: 0.0368
Epoch 9: val_auc improved from 0.99974 to 0.99974, saving model to
best_efficientnet.weights.h5
547/547          181s 330ms/step -
accuracy: 0.9856 - auc: 0.9990 - loss: 0.0368 - val_accuracy: 0.9900 - val_auc:
0.9997 - val_loss: 0.0221 - learning_rate: 2.5000e-06
Epoch 10/50
547/547          0s 320ms/step -
accuracy: 0.9871 - auc: 0.9984 - loss: 0.0388
Epoch 10: val_auc did not improve from 0.99974
547/547          180s 328ms/step -
accuracy: 0.9871 - auc: 0.9984 - loss: 0.0388 - val_accuracy: 0.9896 - val_auc:
0.9997 - val_loss: 0.0217 - learning_rate: 2.5000e-06
Epoch 11/50
547/547          0s 322ms/step -
accuracy: 0.9851 - auc: 0.9986 - loss: 0.0405
Epoch 11: ReduceLROnPlateau reducing learning rate to 1.24999968422344e-06.

Epoch 11: val_auc did not improve from 0.99974
547/547          180s 329ms/step -
accuracy: 0.9851 - auc: 0.9986 - loss: 0.0405 - val_accuracy: 0.9896 - val_auc:
0.9997 - val_loss: 0.0219 - learning_rate: 2.5000e-06
Epoch 12/50
547/547          0s 321ms/step -
accuracy: 0.9869 - auc: 0.9986 - loss: 0.0400
Epoch 12: val_auc did not improve from 0.99974
547/547          179s 328ms/step -
accuracy: 0.9869 - auc: 0.9986 - loss: 0.0400 - val_accuracy: 0.9900 - val_auc:
0.9997 - val_loss: 0.0218 - learning_rate: 1.2500e-06
Epoch 13/50
547/547          0s 321ms/step -
accuracy: 0.9860 - auc: 0.9986 - loss: 0.0412
```

```

Epoch 13: val_auc did not improve from 0.99974
547/547           179s 328ms/step -
accuracy: 0.9860 - auc: 0.9986 - loss: 0.0412 - val_accuracy: 0.9896 - val_auc:
0.9997 - val_loss: 0.0218 - learning_rate: 1.2500e-06
Epoch 14/50
547/547           0s 320ms/step -
accuracy: 0.9868 - auc: 0.9990 - loss: 0.0351
Epoch 14: ReduceLROnPlateau reducing learning rate to 1e-06.

Epoch 14: val_auc did not improve from 0.99974
547/547           179s 327ms/step -
accuracy: 0.9868 - auc: 0.9990 - loss: 0.0351 - val_accuracy: 0.9900 - val_auc:
0.9997 - val_loss: 0.0217 - learning_rate: 1.2500e-06
Epoch 14: early stopping
Restoring model weights from the end of the best epoch: 9.
EfficientNetB0 -> Acc: 0.9916, AUC: 0.9997

```

1.0.14 Plotting the training curves

```
[15]: def hist_to_dict(h):
    if h is None:
        return {}
    if hasattr(h, "history"):
        return h.history
    if isinstance(h, dict):
        return h
    return getattr(h, "history", {})

hc = hist_to_dict(h_custom)
hm = hist_to_dict(h_mb)
he = hist_to_dict(h_eff)
plt.figure(figsize=(14,6))

plt.subplot(1,2,1)
if 'accuracy' in hc:
    plt.plot(hc['accuracy'], label='Custom train', marker='o')
if 'val_accuracy' in hc:
    plt.plot(hc['val_accuracy'], label='Custom val', linestyle='--', marker='o')
if 'accuracy' in hm:
    plt.plot(hm['accuracy'], label='MobileNet train', marker='s')
if 'val_accuracy' in hm:
    plt.plot(hm['val_accuracy'], label='MobileNet val', linestyle='--', marker='s')
if 'accuracy' in he:
    plt.plot(he['accuracy'], label='EffNet train', marker='^')
if 'val_accuracy' in he:
    plt.plot(he['val_accuracy'], label='EffNet val', linestyle='--', marker='^')
```

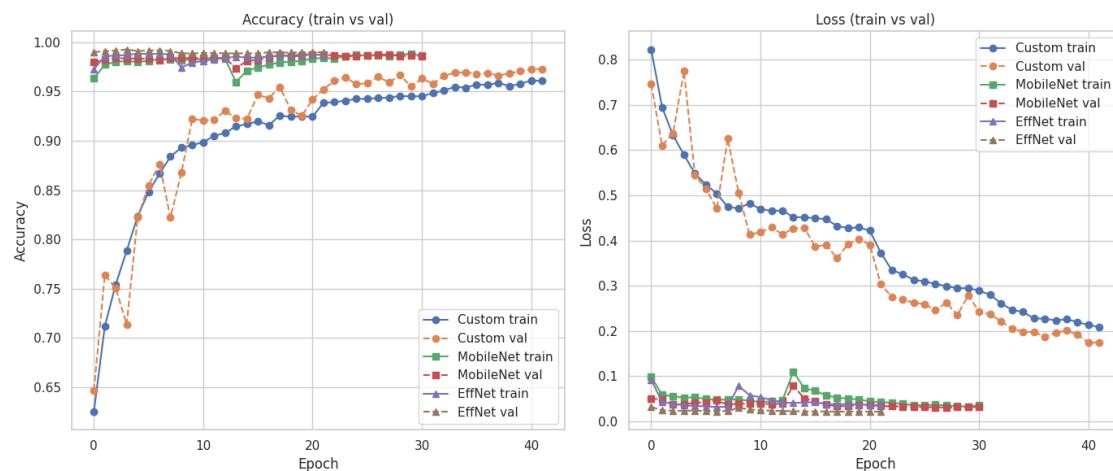
```

plt.title("Accuracy (train vs val)")
plt.xlabel("Epoch")
plt.ylabel("Accuracy")
plt.legend()
plt.grid(True)

plt.subplot(1,2,2)
if 'loss' in hc:
    plt.plot(hc['loss'], label='Custom train', marker='o')
if 'val_loss' in hc:
    plt.plot(hc['val_loss'], label='Custom val', linestyle='--', marker='o')
if 'loss' in hm:
    plt.plot(hm['loss'], label='MobileNet train', marker='s')
if 'val_loss' in hm:
    plt.plot(hm['val_loss'], label='MobileNet val', linestyle='--', marker='s')
if 'loss' in he:
    plt.plot(he['loss'], label='EffNet train', marker='^')
if 'val_loss' in he:
    plt.plot(he['val_loss'], label='EffNet val', linestyle='--', marker='^')
plt.title("Loss (train vs val)")
plt.xlabel("Epoch")
plt.ylabel("Loss")
plt.legend()
plt.grid(True)

plt.tight_layout()
plt.show()

```



[16]: `import seaborn as sns`

```

def eval_model(model, test_gen, name):
    y_prob = model.predict(test_gen, verbose=0).reshape(-1)
    y_pred = (y_prob > 0.5).astype(int)
    y_true = test_gen.classes
    acc = np.mean(y_pred == y_true)
    auc = roc_auc_score(y_true, y_prob)
    print(f"\n== {name} ==\nAccuracy: {acc:.4f} | AUC: {auc:.4f}")
    print(classification_report(y_true, y_pred, target_names=['Cat', 'Dog']))
    cm = confusion_matrix(y_true, y_pred)
    plt.figure(figsize=(4,3)); sns.heatmap(cm, annot=True, fmt='d',
    cmap='Blues', xticklabels=['Cat', 'Dog'], yticklabels=['Cat', 'Dog'])
    plt.title(f"Confusion Matrix - {name}"); plt.xlabel("Predicted");
    plt.ylabel("True"); plt.show()
    return acc, auc

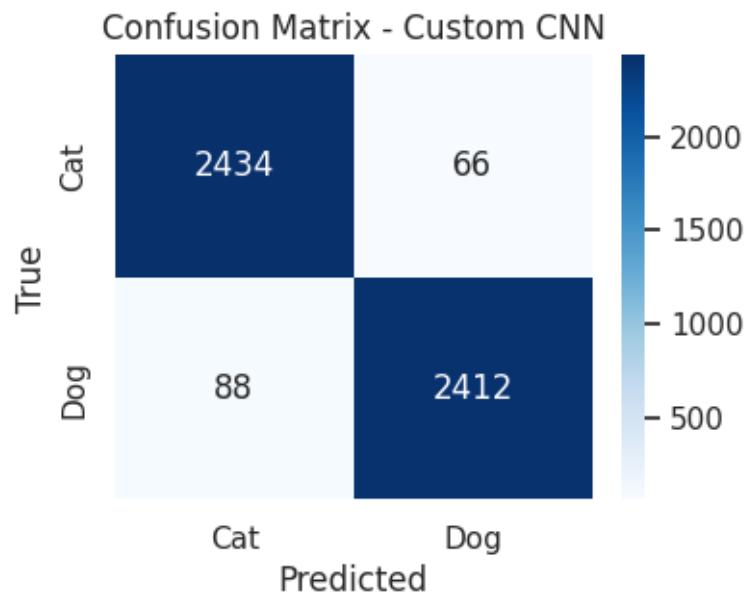
acc_c2, auc_c2 = eval_model(custom_model, test_gen_custom, "Custom CNN")
acc_mb2, auc_mb2 = eval_model(mb_model, test_gen_mb, "MobileNetV2")
acc_eff2, auc_eff2 = eval_model(eff_model, test_gen_eff, "EfficientNetB0")

```

== Custom CNN ==

Accuracy: 0.9692 | AUC: 0.9961

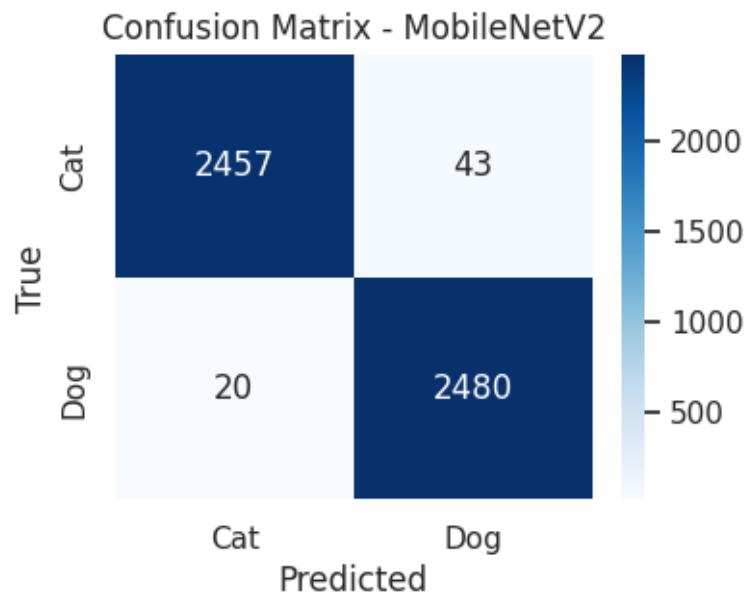
	precision	recall	f1-score	support
Cat	0.97	0.97	0.97	2500
Dog	0.97	0.96	0.97	2500
accuracy			0.97	5000
macro avg	0.97	0.97	0.97	5000
weighted avg	0.97	0.97	0.97	5000



```
==== MobileNetV2 ====
```

```
Accuracy: 0.9874 | AUC: 0.9994
```

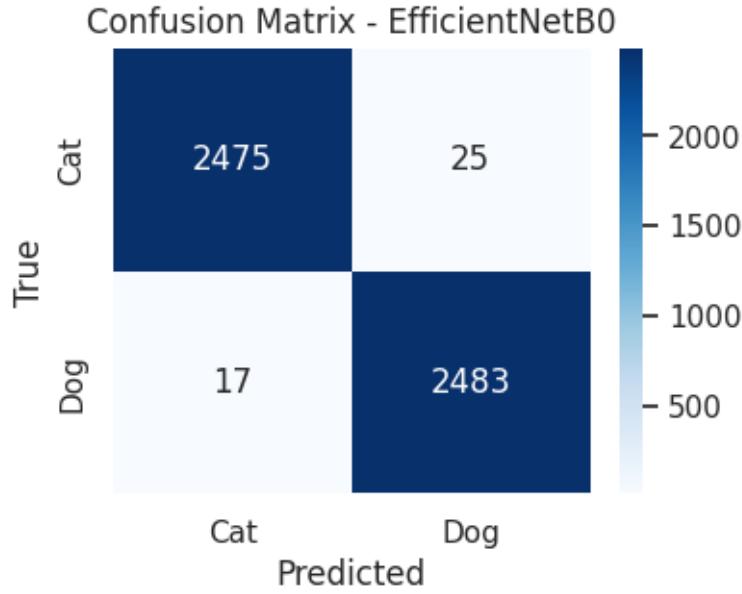
	precision	recall	f1-score	support
Cat	0.99	0.98	0.99	2500
Dog	0.98	0.99	0.99	2500
accuracy			0.99	5000
macro avg	0.99	0.99	0.99	5000
weighted avg	0.99	0.99	0.99	5000



```
==== EfficientNetB0 ====
```

```
Accuracy: 0.9916 | AUC: 0.9997
```

	precision	recall	f1-score	support
Cat	0.99	0.99	0.99	2500
Dog	0.99	0.99	0.99	2500
accuracy			0.99	5000
macro avg	0.99	0.99	0.99	5000
weighted avg	0.99	0.99	0.99	5000



Model	Accuracy	AUC
Custom CNN	0.9692	0.9961
EfficientNetB0	0.9916	0.9997
MobileNetV2	0.9874	0.9994

1.0.15 Comparing the choosing the best model

```
[17]: models_info = {
    'custom': {'model': custom_model, 'acc': acc_c2, 'auc': auc_c2, 'test_gen': test_gen_custom},
    'mobilenet': {'model': mb_model, 'acc': acc_mb2, 'auc': auc_mb2, 'test_gen': test_gen_mb},
    'efficientnet': {'model': eff_model, 'acc': acc_eff2, 'auc': auc_eff2, 'test_gen': test_gen_eff}
}

sorted_models = sorted(models_info.items(), key=lambda kv: (kv[1]['acc'], kv[1]['auc']), reverse=True)
best_key, best_info = sorted_models[0]
best_model = best_info['model']
best_test_gen = best_info['test_gen']
print("Best model chosen:", best_key, f"(Acc={best_info['acc']:.4f}, AUC={best_info['auc']:.4f})")

# Saving the best model
```

```

best_full = "best_overall.keras"
best_weights = "best_overall.weights.h5"
meta = {"model_key": best_key, "img_size": IMG_SIZE}
try:
    best_model.save(best_full)
    print("Saved full best model to", best_full)
    best_model.save_weights(best_weights)
    print("Saved weights to", best_weights)
except Exception as e:
    print("Full save failed:", e, "Saving weights only.")
    best_model.save_weights(best_weights)

with open("best_overall.meta.json", "w") as f:
    json.dump(meta, f)
print("Saved metadata to best_overall.meta.json:", meta)

```

Best model chosen: efficientnet (Acc=0.9916, AUC=0.9997)
Saved full best model to best_overall.keras
Saved weights to best_overall.weights.h5
Saved metadata to best_overall.meta.json: {'model_key': 'efficientnet',
'img_size': 224}

[]:

1.0.16 Sample prediction

```

[18]: def preprocess_path(path, model_key):
    img = Image.open(path).convert("RGB").resize((IMG_SIZE,IMG_SIZE))
    arr = np.array(img).astype(np.float32)
    arr = np.expand_dims(arr, axis=0)
    if model_key == 'mobilenet':
        return mb_preprocess(arr)
    elif model_key == 'efficientnet':
        return eff_preprocess(arr)
    else:
        return arr / 255.0

test_files = best_test_gen.filepaths
n = min(8, len(test_files))
indices = random.sample(range(len(test_files)), n)

plt.figure(figsize=(16,8))
for i, idx in enumerate(indices):
    fp = test_files[idx]
    actual = "Dog" if best_test_gen.classes[idx]==1 else "Cat"
    x = preprocess_path(fp, best_key)
    prob = float(best_model.predict(x, verbose=0).reshape(-1)[0])
    pred = "Dog" if prob>0.5 else "Cat"

```

```

conf = prob if prob>0.5 else 1.0 - prob
plt.subplot(2,4,i+1)
plt.imshow(Image.open(fp))
plt.title(f"Actual: {actual}\nPred: {pred} ({conf*100:.1f}%)")
plt.axis('off')
plt.suptitle(f"Sample predictions by best model: {best_key.upper()}")
plt.tight_layout(rect=[0,0,1,0.96])
plt.show()

```

Sample predictions by best model: EFFICIENTNET

