```
# STEP 1: Install & authenticate Kaggle
!pip install -q kaggle

# Upload your Kaggle API key (kaggle.json)
from google.colab import files
files.upload()  # Upload the kaggle.json file

# Create kaggle folder and move the key
!mkdir -p ~/.kaggle
!cp kaggle.json ~/.kaggle/
!chmod 600 ~/.kaggle/kaggle.json


# STEP 2: Download the Animals-10 dataset
!kaggle datasets download -d alessiocorrado99/animals10

# Unzip the dataset
!unzip -q animals10.zip -d animals10
```

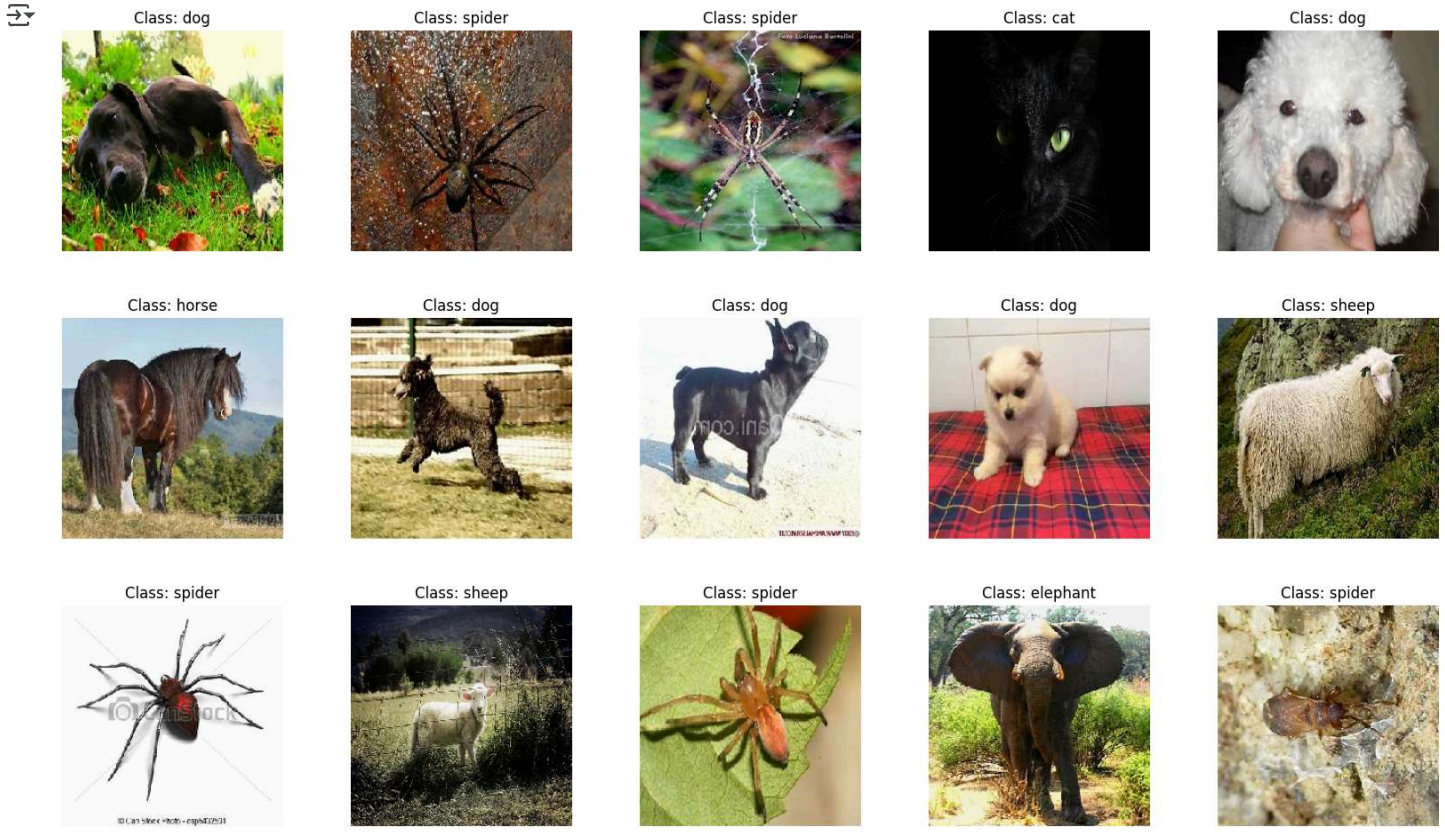
```
Choose Files No file chosen  Upload widget is only available when the cell has been executed in the current browser session. Please rerun this cell to enable.
Saving kaggle.json to kaggle.json
Dataset URL: https://www.kaggle.com/datasets/alessiocorrado99/animals10
License(s): GPL-2.0
```

```
translate = {
    "cane": "dog",
    "cavallo": "horse",
    "elefante": "elephant",
    "farfalla": "butterfly",
    "gallina": "chicken",
    "gatto": "cat",
    "mucca": "cow",
    "pecora": "sheep",
    "ragno": "spider",
    "scoiattolo": "squirrel",
}


directory=r"/content/animals10/raw-img"
batch_size = 32
img_size = 224


from tensorflow.keras.preprocessing.image import ImageDataGenerator, load_img, img_to_array


datagen = ImageDataGenerator(
    rescale=1/255.,
    horizontal_flip=True,
    validation_split=0.15
)


train_generator = datagen.flow_from_directory(
    directory,
    target_size=(img_size, img_size),
    batch_size=batch_size,
    shuffle=True,
    subset='training',
    class_mode='categorical'
)


validation_generator = datagen.flow_from_directory( directory,
  target_size=(img_size, img_size),
   batch_size=batch_size,
    shuffle=False,
   subset='validation',
   class_mode='categorical'
)
```

```
Found 22257 images belonging to 10 classes.
Found 3922 images belonging to 10 classes.
```

```
import numpy as np
import matplotlib.pyplot as plt
```

```
labels = [k for k in train_generator.class_indices]
translated_labels = [translate[label] for label in labels]
sample_generate = train_generator.__next__()
images = sample_generate[0]
titles = sample_generate[1]
plt.figure(figsize=(20, 20))


for i in range(15):
    plt.subplot(5, 5, i+1)
    plt.subplots_adjust(hspace=0.3, wspace=0.3)
    plt.imshow(images[i])
    plt.title(f'Class: {translated_labels[np.argmax(titles[i], axis=0)]}')
    plt.axis("off")

plt.show()
```




```
import tensorflow as tf
from tensorflow.keras.layers import (Conv2D, MaxPooling2D, AveragePooling2D, Flatten, Dense, Input, Dropout,
                                     concatenate)
from tensorflow.keras.models import Sequential, Model
from tensorflow.keras.applications import VGG16
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.utils import to_categorical
import matplotlib.pyplot as plt
import numpy as np
import os
import time


img_size = 224


base_model = VGG16(include_top=False,
                   weights='imagenet',
```

```
                  input_shape=(img_size, img_size, 3))

base_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.
58889256/58889256 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
Model: "vgg16"
```

Layer (type)	Output Shape	Param #
input_layer (InputLayer)	(None, 224, 224, 3)	0
block1_conv1 (Conv2D)	(None, 224, 224, 64)	1,792
block1_conv2 (Conv2D)	(None, 224, 224, 64)	36,928
block1_pool (MaxPooling2D)	(None, 112, 112, 64)	0
block2_conv1 (Conv2D)	(None, 112, 112, 128)	73,856
block2_conv2 (Conv2D)	(None, 112, 112, 128)	147,584
block2_pool (MaxPooling2D)	(None, 56, 56, 128)	0
block3_conv1 (Conv2D)	(None, 56, 56, 256)	295,168
block3_conv2 (Conv2D)	(None, 56, 56, 256)	590,080
block3_conv3 (Conv2D)	(None, 56, 56, 256)	590,080
block3_pool (MaxPooling2D)	(None, 28, 28, 256)	0
block4_conv1 (Conv2D)	(None, 28, 28, 512)	1,180,160
block4_conv2 (Conv2D)	(None, 28, 28, 512)	2,359,808
block4_conv3 (Conv2D)	(None, 28, 28, 512)	2,359,808
block4_pool (MaxPooling2D)	(None, 14, 14, 512)	0
block5_conv1 (Conv2D)	(None, 14, 14, 512)	2,359,808
block5_conv2 (Conv2D)	(None, 14, 14, 512)	2,359,808
block5_conv3 (Conv2D)	(None, 14, 14, 512)	2,359,808
block5_pool (MaxPooling2D)	(None, 7, 7, 512)	0

```
Total params: 14,714,688 (56.13 MB)
Trainable params: 14,714,688 (56.13 MB)
```

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense

def build_zfnet():
    model = Sequential([
        Conv2D(96, (7,7), strides=(2,2), activation='relu', input_shape=(224,224,3)),
        MaxPooling2D((3,3), strides=(2,2)),
        Conv2D(256, (5,5), strides=(2,2), activation='relu'),
        MaxPooling2D((3,3), strides=(2,2)),
        Conv2D(384, (3,3), activation='relu'),
        Conv2D(384, (3,3), activation='relu'),
        Conv2D(256, (3,3), activation='relu'),
        MaxPooling2D((3,3), strides=(2,2)),
        Flatten(),
        Dense(4096, activation='relu'),
        Dense(4096, activation='relu'),
        Dense(10, activation='softmax')
    ])
    model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
    return model


from tensorflow.keras.applications import VGG16
from tensorflow.keras.models import Model
from tensorflow.keras.layers import GlobalAveragePooling2D, Dense

def build_vgg16():
    base = VGG16(weights='imagenet', include_top=False, input_shape=(224,224,3))
    for layer in base.layers:
        layer.trainable = False
```

```
    x = GlobalAveragePooling2D()(base.output)
    x = Dense(256, activation='relu')(x)
    output = Dense(10, activation='softmax')(x)
    model = Model(base.input, output)
    model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
    return model


import tensorflow as tf
from tensorflow.keras.layers import Conv2D, MaxPooling2D, AveragePooling2D, Flatten, Dense, Input, concatenate
from tensorflow.keras.models import Model
from tensorflow.keras.preprocessing.image import ImageDataGenerator
import matplotlib.pyplot as plt


import tensorflow as tf
from tensorflow.keras.layers import Conv2D, MaxPooling2D, AveragePooling2D, Flatten, Dense, Input, concatenate
from tensorflow.keras.models import Model
from tensorflow.keras.preprocessing.image import ImageDataGenerator
import matplotlib.pyplot as plt

# --- Define Inception Module ---
def inception_module(x, f1, f3r, f3, f5r, f5, pool_proj):
    conv1 = Conv2D(f1, (1,1), padding='same', activation='relu')(x)
    conv3 = Conv2D(f3r, (1,1), padding='same', activation='relu')(x)
    conv3 = Conv2D(f3, (3,3), padding='same', activation='relu')(conv3)
    conv5 = Conv2D(f5r, (1,1), padding='same', activation='relu')(x)
    conv5 = Conv2D(f5, (5,5), padding='same', activation='relu')(conv5)
    pool = MaxPooling2D((3,3), strides=(1,1), padding='same')(x)
    pool = Conv2D(pool_proj, (1,1), padding='same', activation='relu')(pool)
    output = concatenate([conv1, conv3, conv5, pool], axis=3)
    return output

# --- Build Inception V1 Model ---
def build_inception_v1(input_shape=(224, 224, 3), num_classes=10):
    input_layer = Input(shape=input_shape)

    x = Conv2D(64, (7,7), strides=(2,2), padding='same', activation='relu')(input_layer)
    x = MaxPooling2D((3,3), strides=(2,2), padding='same')(x)
    x = Conv2D(64, (1,1), activation='relu')(x)
    x = Conv2D(192, (3,3), padding='same', activation='relu')(x)
    x = MaxPooling2D((3,3), strides=(2,2), padding='same')(x)

    x = inception_module(x, 64, 96, 128, 16, 32, 32)
    x = inception_module(x, 128, 128, 192, 32, 96, 64)
    x = MaxPooling2D((3,3), strides=(2,2), padding='same')(x)

    x = inception_module(x, 192, 96, 208, 16, 48, 64)
    x = inception_module(x, 160, 112, 224, 24, 64, 64)
    x = inception_module(x, 128, 128, 256, 24, 64, 64)
    x = inception_module(x, 112, 144, 288, 32, 64, 64)
    x = inception_module(x, 256, 160, 320, 32, 128, 128)
    x = MaxPooling2D((3,3), strides=(2,2), padding='same')(x)

    x = inception_module(x, 256, 160, 320, 32, 128, 128)
    x = inception_module(x, 384, 192, 384, 48, 128, 128)

    x = AveragePooling2D(pool_size=(7,7), strides=(1,1))(x)
    x = Flatten()(x)
    x = Dense(1024, activation='relu')(x)
    x = Dense(num_classes, activation='softmax')(x)

    model = Model(input_layer, x)
    model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
    return model


models = {
    "ZFNet": build_zfnet(),
    "VGG16": build_vgg16(),
    "InceptionV1": build_inception_v1()
}
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/convolutional/base_conv.py:107: UserWarning: Do not pass an `input_shape`/`inpu
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
import time
import matplotlib.pyplot as plt
from tensorflow.keras.callbacks import EarlyStopping, ReduceLROnPlateau
histories = {}
results = {}

for name, model in models.items():
    print(f"\n--- Training {name} ---")
    start_time = time.time()
    default_epochs = 20
    callbacks = []


    if name.lower() == "zfnet":
        epochs = 20
        callbacks = [
            EarlyStopping(monitor='val_loss', patience=3, restore_best_weights=True),
            ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=2, verbose=1)
        ]
    else:
        epochs = default_epochs
        callbacks = [
            EarlyStopping(monitor='val_loss', patience=5, restore_best_weights=True)
        ]

    history = model.fit(
        train_generator,
        validation_data=validation_generator,
        epochs=epochs,
        verbose=1,
        callbacks=callbacks
    )

    end_time = time.time()

    val_loss, val_acc = model.evaluate(validation_generator, verbose=0)
    print(f"{name} Validation Accuracy: {val_acc:.4f}")
    print(f"{name} Training Time: {end_time - start_time:.2f} seconds")


    histories[name] = history
    results[name] = {
        'val_accuracy': val_acc,
        'training_time': end_time - start_time
    }

    save_path = f'{name}_model.keras'
    model.save(save_path)
    print(f"{name} model saved to {save_path}")


def plot_histories(histories):
    for name, history in histories.items():
        plt.figure(figsize=(12, 5))
        plt.suptitle(f'{name} Training Performance', fontsize=16)

        # Accuracy
        plt.subplot(1, 2, 1)
        plt.plot(history.history['accuracy'], label='Train Accuracy')
        plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
        plt.title('Accuracy')
        plt.xlabel('Epochs')
        plt.ylabel('Accuracy')
        plt.legend()

        # Loss
        plt.subplot(1, 2, 2)
        plt.plot(history.history['loss'], label='Train Loss')
        plt.plot(history.history['val_loss'], label='Validation Loss')
        plt.title('Loss')
        plt.xlabel('Epochs')
        plt.ylabel('Loss')
        plt.legend()

        plt.show()

plot_histories(histories)
```

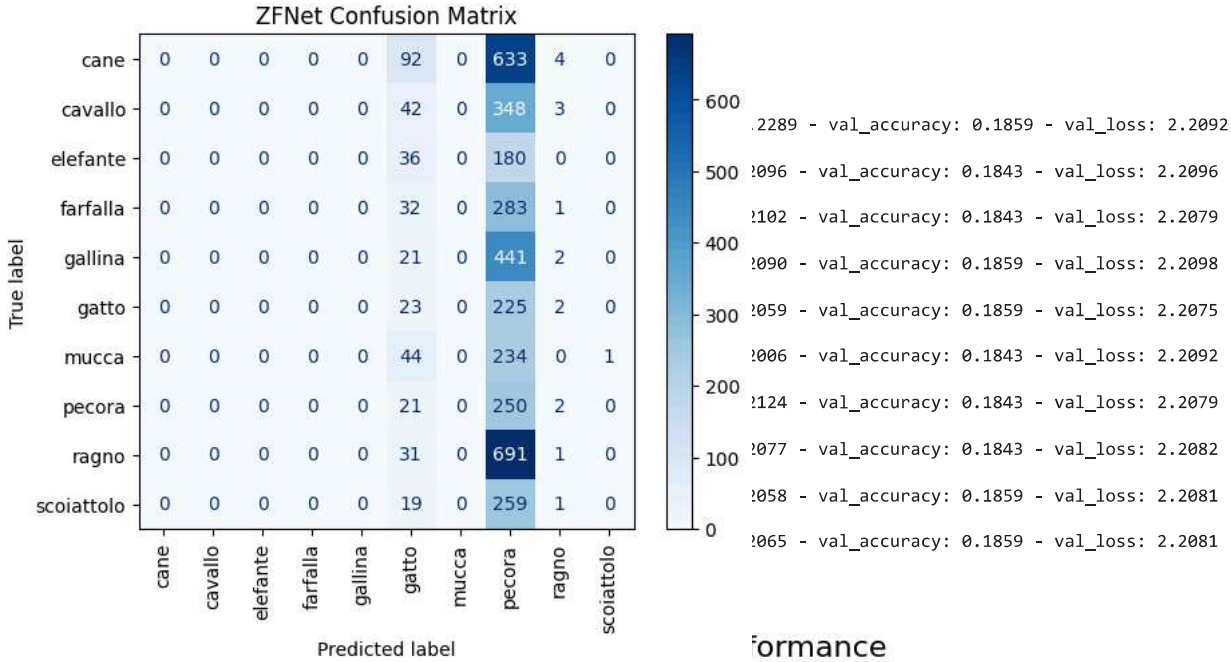
```
print("\n--- Final Evaluation Summary ---")
for name, data in results.items():
    print(f"{name}:")
    print(f"  Validation Accuracy: {data['val_accuracy']:.4f}")
    print(f"  Training Time: {data['training_time']:.2f} seconds\n")
```

```
--- Training ZFNet ---
/usr/local/lib/python3.11/dist-packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121: UserWarning: Your `PyDataset` class
  self._warn_if_super_not_called()
Epoch 1/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 74s 94ms/step - accuracy: 0.2261 - loss: 2.2471 - val_accuracy: 0.3343 - val_loss: 1.8556 - learning_rate:
Epoch 2/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 62s 90ms/step - accuracy: 0.3550 - loss: 1.8385 - val_accuracy: 0.3921 - val_loss: 1.7264 - learning_rate:
Epoch 3/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 59s 84ms/step - accuracy: 0.4067 - loss: 1.6904 - val_accuracy: 0.4151 - val_loss: 1.6455 - learning_rate:
Epoch 4/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 61s 88ms/step - accuracy: 0.4655 - loss: 1.5416 - val_accuracy: 0.4906 - val_loss: 1.4824 - learning_rate:
Epoch 5/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 61s 88ms/step - accuracy: 0.5242 - loss: 1.4050 - val_accuracy: 0.5709 - val_loss: 1.2619 - learning_rate:
Epoch 6/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 57s 82ms/step - accuracy: 0.5604 - loss: 1.2975 - val_accuracy: 0.5745 - val_loss: 1.2563 - learning_rate:
Epoch 7/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 59s 85ms/step - accuracy: 0.5822 - loss: 1.2384 - val_accuracy: 0.6045 - val_loss: 1.1593 - learning_rate:
Epoch 8/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 58s 83ms/step - accuracy: 0.6002 - loss: 1.1827 - val_accuracy: 0.6114 - val_loss: 1.1510 - learning_rate:
Epoch 9/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 62s 89ms/step - accuracy: 0.6246 - loss: 1.1060 - val_accuracy: 0.6334 - val_loss: 1.0931 - learning_rate:
Epoch 10/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 60s 87ms/step - accuracy: 0.6404 - loss: 1.0590 - val_accuracy: 0.6397 - val_loss: 1.0519 - learning_rate:
Epoch 11/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 58s 83ms/step - accuracy: 0.6619 - loss: 1.0062 - val_accuracy: 0.6543 - val_loss: 1.0477 - learning_rate:
Epoch 12/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 58s 83ms/step - accuracy: 0.6725 - loss: 0.9591 - val_accuracy: 0.6548 - val_loss: 1.0339 - learning_rate:
Epoch 13/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 59s 85ms/step - accuracy: 0.6917 - loss: 0.9141 - val_accuracy: 0.6586 - val_loss: 1.0300 - learning_rate:
Epoch 14/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 58s 83ms/step - accuracy: 0.7044 - loss: 0.8771 - val_accuracy: 0.6708 - val_loss: 1.0239 - learning_rate:
Epoch 15/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 57s 82ms/step - accuracy: 0.7134 - loss: 0.8535 - val_accuracy: 0.6711 - val_loss: 1.0146 - learning_rate:
Epoch 16/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 84s 84ms/step - accuracy: 0.7209 - loss: 0.8344 - val_accuracy: 0.6795 - val_loss: 0.9792 - learning_rate:
Epoch 17/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 62s 88ms/step - accuracy: 0.7330 - loss: 0.7855 - val_accuracy: 0.6902 - val_loss: 0.9513 - learning_rate:
Epoch 18/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 59s 85ms/step - accuracy: 0.7495 - loss: 0.7424 - val_accuracy: 0.6527 - val_loss: 1.1038 - learning_rate:
Epoch 19/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 0s 72ms/step - accuracy: 0.7518 - loss: 0.7374
Epoch 19: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.
696/696 ━━━━━━━━━━━━━━━━━━━━ 56s 81ms/step - accuracy: 0.7518 - loss: 0.7374 - val_accuracy: 0.6887 - val_loss: 0.9757 - learning_rate:
Epoch 20/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 58s 83ms/step - accuracy: 0.7968 - loss: 0.5949 - val_accuracy: 0.7104 - val_loss: 0.9704 - learning_rate:
ZFNet Validation Accuracy: 0.6920
ZFNet Training Time: 1223.46 seconds
ZFNet model saved to ZFNet_model.keras

--- Training VGG16 ---
Epoch 1/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 183s 242ms/step - accuracy: 0.5806 - loss: 1.2896 - val_accuracy: 0.7772 - val_loss: 0.6776
Epoch 2/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 149s 214ms/step - accuracy: 0.7932 - loss: 0.6285 - val_accuracy: 0.8027 - val_loss: 0.5926
Epoch 3/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 149s 214ms/step - accuracy: 0.8246 - loss: 0.5380 - val_accuracy: 0.8108 - val_loss: 0.5553
```

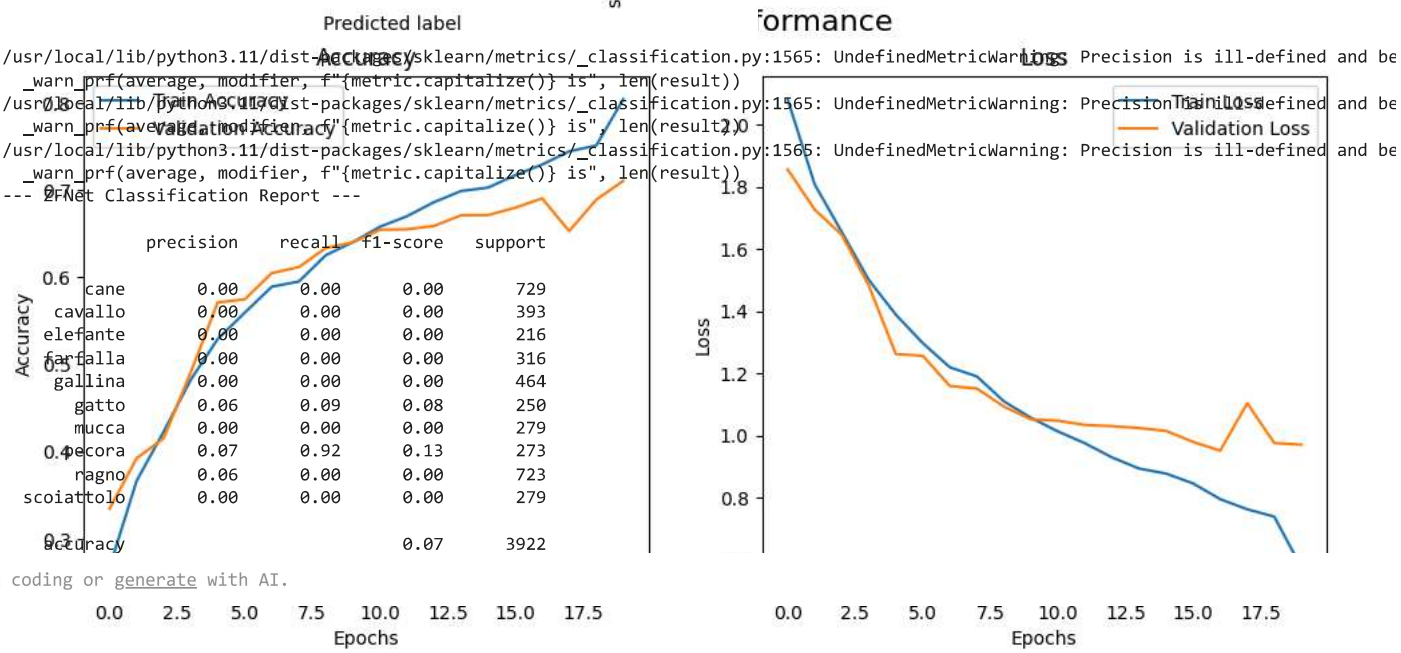
```
from sklearn.metrics import confusion_matrix, classification_report, ConfusionMatrixDisplay
import numpy as np
import matplotlib.pyplot as plt

def evaluate_model(model, generator, class_names, model_name):

    true_labels = generator.classes
    predictions = model.predict(generator, verbose=1)
    predicted_labels = np.argmax(predictions, axis=1)
    cm = confusion_matrix(true_labels, predicted_labels)
    plt.figure(figsize=(10, 8))
    disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=class_names)
    disp.plot(cmap='Blues', xticks_rotation='vertical', values_format='d')
    plt.title(f'{model_name} Confusion Matrix')
    plt.show()
    report = classification_report(true_labels, predicted_labels, target_names=class_names)
```

```
    print(f"--- {model_name} Classification Report ---\n")
    print(report)
class_names = list(validation_generator.class_indices.keys())

for name, model in models.items():
    print(f"\n--- Evaluating {name} ---")
    evaluate_model(model, validation_generator, class_names, name)
```

```
Epoch 18/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 149s 214ms/step - accuracy: 0.8959 - loss: 0.3053 - val_accuracy: 0.8623 - val_loss: 0.4294
Epoch 19/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 149s 214ms/step - accuracy: 0.8974 - loss: 0.2954 - val_accuracy: 0.8726 - val_loss: 0.4062
Epoch 20/20
696/696 ━━━━━━━━━━━━━━━━━━━━ 149s 214ms/step - accuracy: 0.8985 - loss: 0.2947 - val_accuracy: 0.8692 - val_loss: 0.4020
ZFNet validation Accuracy: 0.8755
Evaluating ZFNet ---
/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()
123/123 ━━━━━━━━━━━━━━━━━━━━ 16s 1s/step
<Figure size 1000x800 with 0 Axes>
```



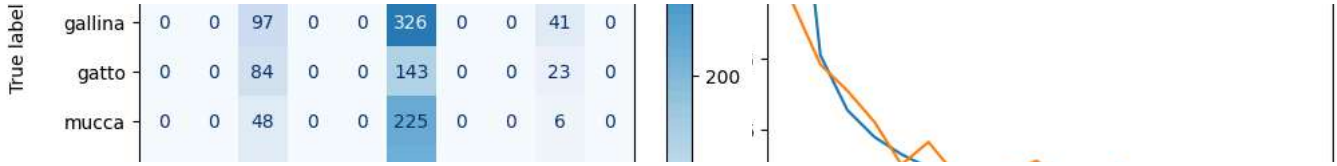

```
2289 - val_accuracy: 0.1859 - val_loss: 2.2092
2096 - val_accuracy: 0.1843 - val_loss: 2.2096
2102 - val_accuracy: 0.1843 - val_loss: 2.2079
2090 - val_accuracy: 0.1859 - val_loss: 2.2098
2059 - val_accuracy: 0.1859 - val_loss: 2.2075
2006 - val_accuracy: 0.1843 - val_loss: 2.2092
2124 - val_accuracy: 0.1843 - val_loss: 2.2079
2077 - val_accuracy: 0.1843 - val_loss: 2.2082
2058 - val_accuracy: 0.1859 - val_loss: 2.2081
2065 - val_accuracy: 0.1859 - val_loss: 2.2081
```




```
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565: UndefinedMetricWarning: Precision is ill-defined and be
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565: UndefinedMetricWarning: Precision is ill-defined and be
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565: UndefinedMetricWarning: Precision is ill-defined and be
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
--- ZFNet Classification Report ---

              precision    recall  f1-score   support

        cane       0.00      0.00      0.00       729
     cavallo       0.00      0.00      0.00       393
    elefante       0.00      0.00      0.00       216
    farfalla       0.00      0.00      0.00       316
     gallina       0.00      0.00      0.00       464
       gatto       0.06      0.09      0.08       250
       mucca       0.00      0.00      0.00       279
      pecora       0.07      0.92      0.13       273
       ragno       0.06      0.00      0.00       723
  scoiattolo       0.00      0.00      0.00       279

    accuracy                           0.07      3922
```

Start coding or generate with AI.

```
--- Evaluating VGG16 ---
123/123 ━━━━━━━━━━━━━━━━━━━━ 2279s 19s/step
<Figure size 1000x800 with 0 Axes>
```


True label
gallina 0 0 97 0 0 326 0 0 41 0
gatto 0 0 84 0 0 143 0 0 23 0
mucca 0 0 48 0 0 225 0 0 6 0
200