DLP_Project_ResNet

May 12, 2025

```
[8]: !pip install tensorflow numpy pandas opencv-python matplotlib scikit-learn
     ↪kagglehub
```

Requirement already satisfied: tensorflow in /usr/local/lib/python3.11/dist-
packages (2.18.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages
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Requirement already satisfied: absl-py>=1.0.0 in /usr/local/lib/python3.11/dist-
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Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-
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Requirement already satisfied:
protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<6.0.0dev,>=3.20.3
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/usr/local/lib/python3.11/dist-packages (from scikit-learn) (3.6.0)
Requirement already satisfied: pyyaml in /usr/local/lib/python3.11/dist-packages
(from kagglehub) (6.0.2)
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Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-packages (from kagglehub) (4.67.1)
Requirement already satisfied: wheel<1.0,>=0.23.0 in /usr/local/lib/python3.11/dist-packages (from astunparse>=1.6.0->tensorflow) (0.45.1)
Requirement already satisfied: rich in /usr/local/lib/python3.11/dist-packages (from keras>=3.5.0->tensorflow) (13.9.4)
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Requirement already satisfied: pygments<3.0.0,>=2.13.0 in /usr/local/lib/python3.11/dist-packages (from rich->keras>=3.5.0->tensorflow) (2.19.1)
Requirement already satisfied: mdurl~=0.1 in /usr/local/lib/python3.11/dist-packages (from markdown-it-py>=2.2.0->rich->keras>=3.5.0->tensorflow) (0.1.2)

```python
import os
import cv2
import numpy as np
import random
```

```python
import matplotlib.pyplot as plt
from tqdm import tqdm
from collections import Counter

from sklearn.model_selection import train_test_split
from sklearn.preprocessing import LabelEncoder
from sklearn.utils.class_weight import compute_class_weight

import tensorflow as tf
from tensorflow.keras.utils import to_categorical
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.applications import ResNet50
from tensorflow.keras.applications.resnet50 import preprocess_input
from tensorflow.keras.layers import Conv2D, Input, Dense, Dropout,␣
 ↪GlobalAveragePooling2D,Lambda,BatchNormalization,MaxPooling2D,Flatten
from tensorflow.keras.models import Model
from tensorflow.keras.callbacks import EarlyStopping, ReduceLROnPlateau
from tensorflow.keras import backend as K
```

```python
[10]: import kagglehub
      path = kagglehub.dataset_download("tejasreddy/iam-handwriting-top50")
      print("Path to dataset files:", path)
```

Path to dataset files: /kaggle/input/iam-handwriting-top50

```python
[11]: image_dir = '/kaggle/input/iam-handwriting-top50/data_subset/data_subset'
      txt_path = '/kaggle/input/iam-handwriting-top50/forms_for_parsing.txt'
```

```python
[12]: def preprocess_image(image_path, target_size=(224,224)):
          img = cv2.imread(image_path)
          img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
          img = cv2.resize(img, target_size)
          img = preprocess_input(img.astype(np.float32))
          return img
```

```python
[13]: form_writer_map = {}
      with open(txt_path, 'r') as f:
          for line in f:
              if line.strip():
                  parts = line.strip().split()
                  if len(parts) >= 2:
                      form_id, writer_id = parts[0], parts[1]
                      form_writer_map[form_id] = writer_id
```

```python
[7]: data, labels = [], []
     for fname in tqdm(os.listdir(image_dir)):
         if fname.lower().endswith(('.png', '.jpg', '.jpeg')):
```

```
            form_id = os.path.splitext(fname)[0].split("-s")[0]
            if form_id in form_writer_map:
                label = form_writer_map[form_id]
                img_path = os.path.join(image_dir, fname)
                img = preprocess_image(img_path)
                data.append(img)
                labels.append(label)
X = np.array(data)
y = np.array(labels)
```

100%| | 4899/4899 [00:41<00:00, 117.36it/s]

[14]:
```python
from collections import Counter
label_counts = Counter(labels)
top_writers = [writer for writer, count in label_counts.most_common(10)]

filtered_data = []
filtered_labels = []
for img, label in zip(data, labels):
    if label in top_writers:
        filtered_data.append(img)
        filtered_labels.append(label)

X = np.array(filtered_data)
y = np.array(filtered_labels)
```

[15]:
```python
le = LabelEncoder()
y_encoded = le.fit_transform(y)
y_categorical = to_categorical(y_encoded)
```

[16]:
```python
X_train, X_test, y_train, y_test = train_test_split(X, y_categorical,
 ↪test_size=0.2, random_state=42)
```
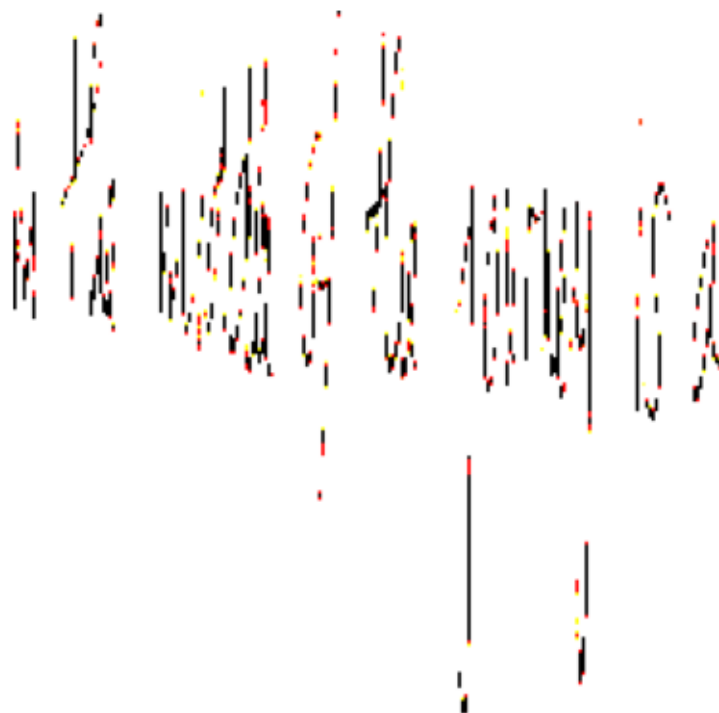
[17]:
```python
import matplotlib.pyplot as plt

for i in range(10):
    plt.imshow(X_train[i].squeeze(), cmap='gray')
    label = le.inverse_transform([np.argmax(y_train[i])])[0]
    plt.title(f"Label: {label}")
    plt.axis('off')
    plt.show()
```
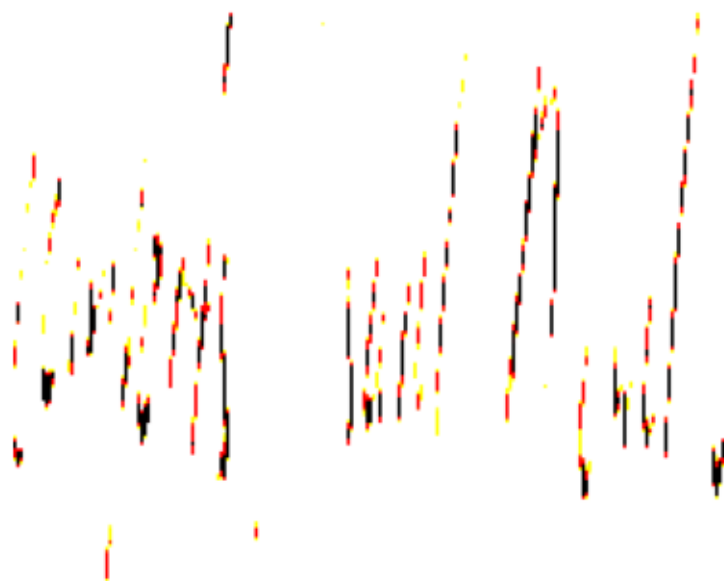
WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
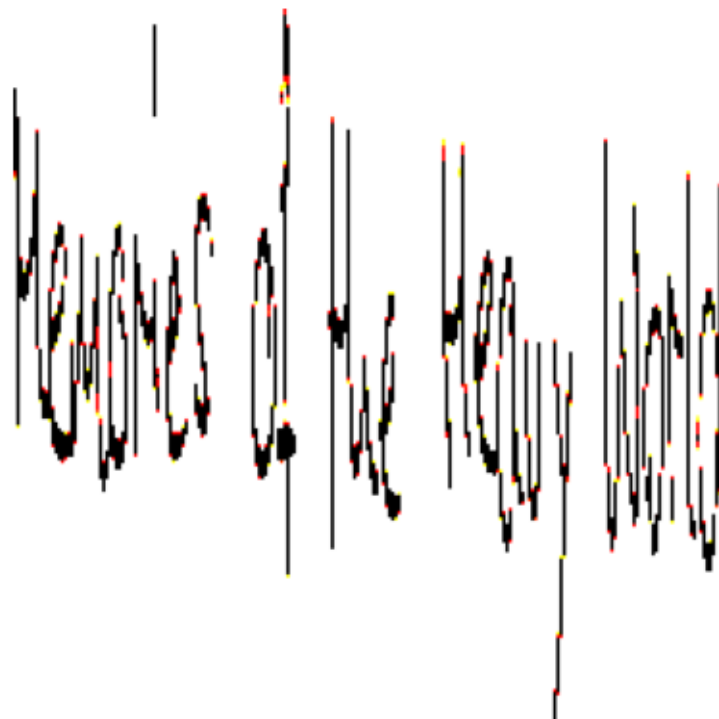[-87.68..151.061].

Label: 670

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
[-63.68..151.061].

Label: 551

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
[-99.68..151.061].

Label: 552

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). Got range [-86.68..151.061].

Label: 153

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). Got range [-89.68..151.061].
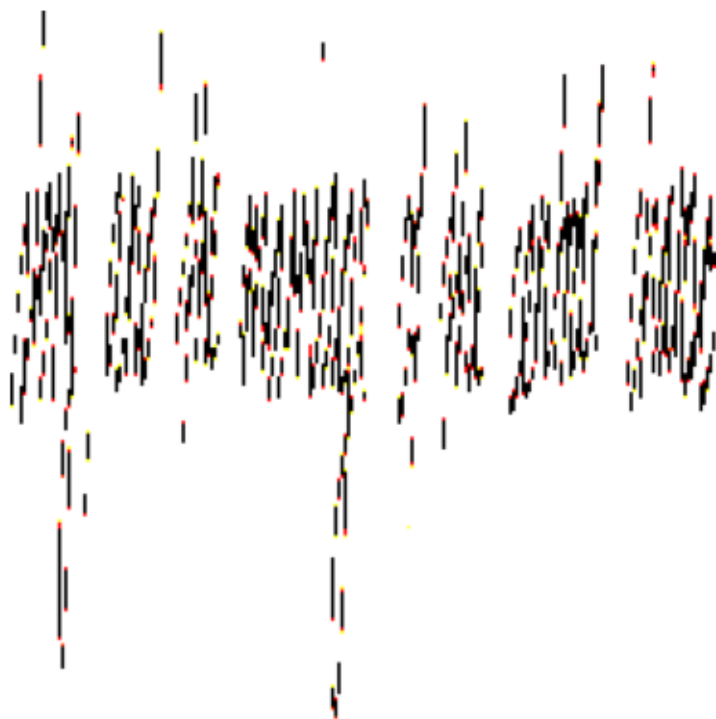
Label: 670

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
[-70.68..151.061].

Label: 384

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). Got range [-86.68..151.061].
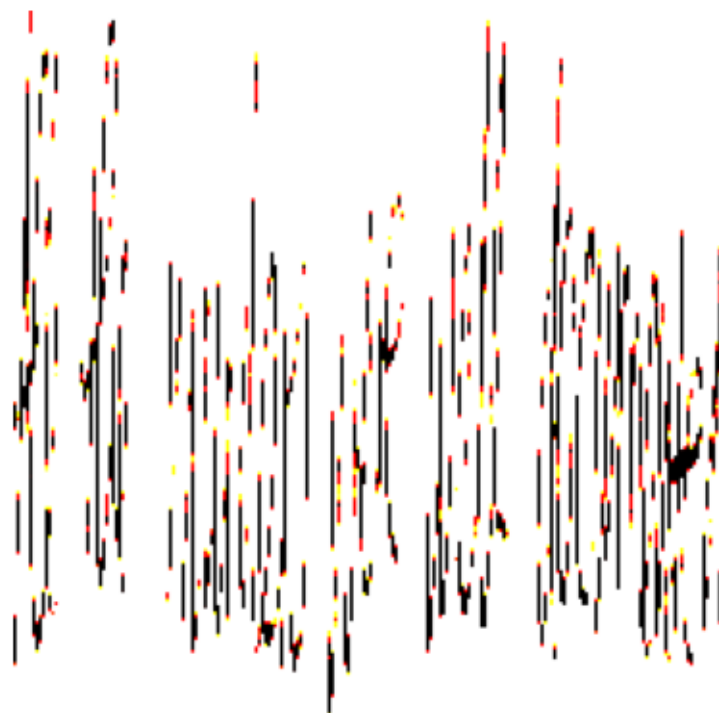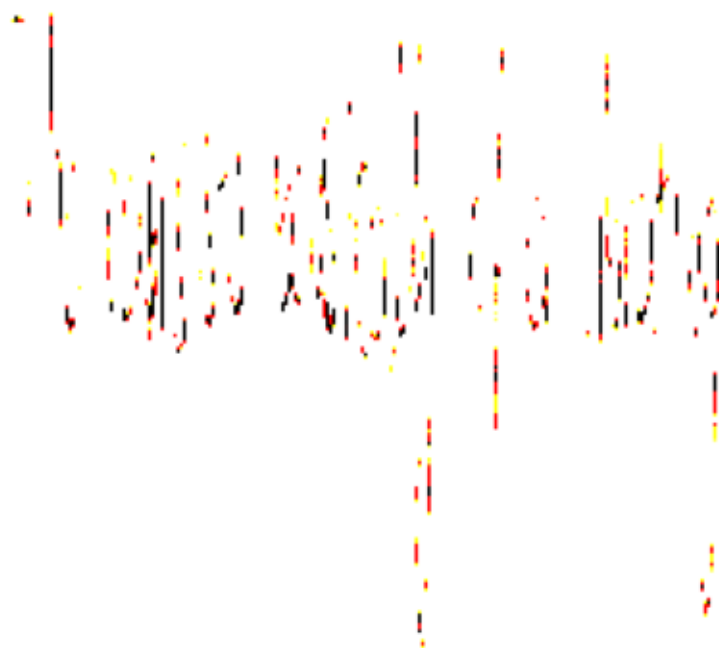
Label: 634

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
[-90.68..151.061].

Label: 000

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
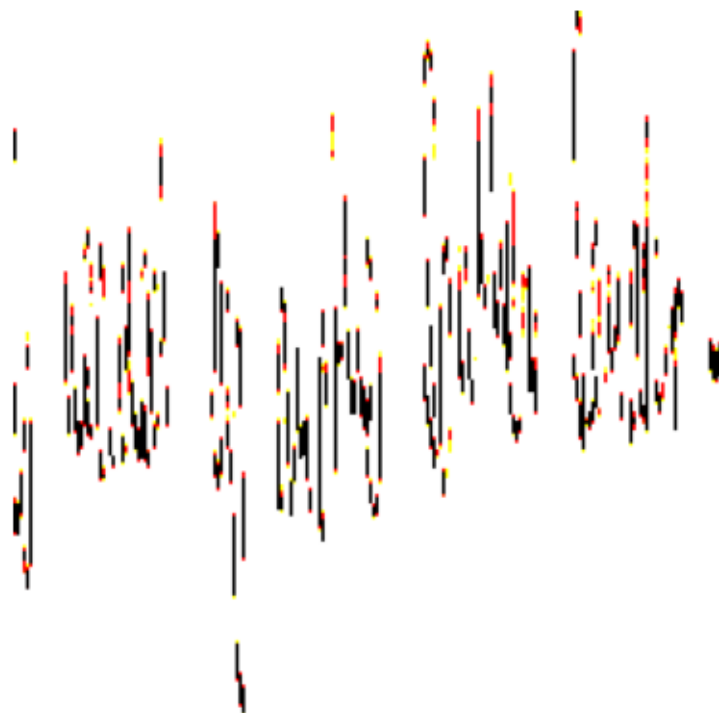[-100.68..151.061].

Label: 552
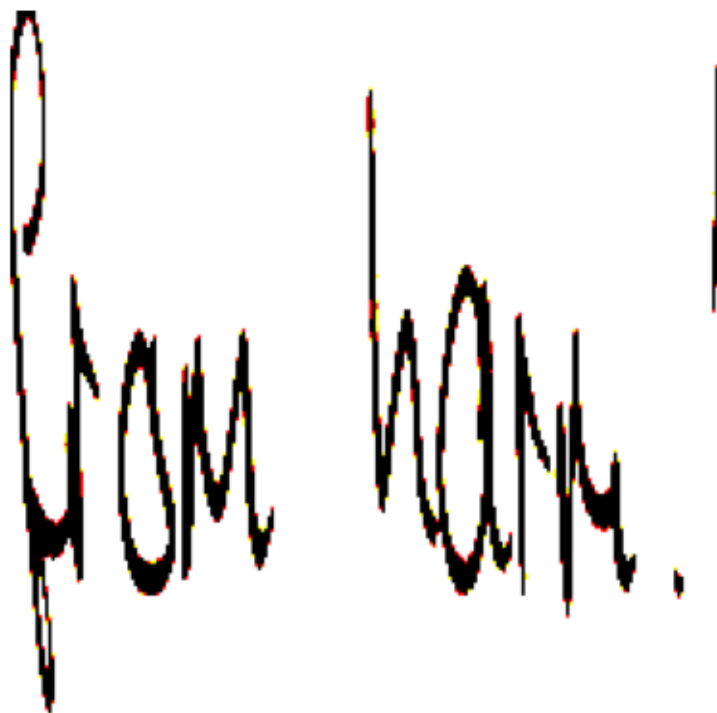

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
[-76.68..151.061].

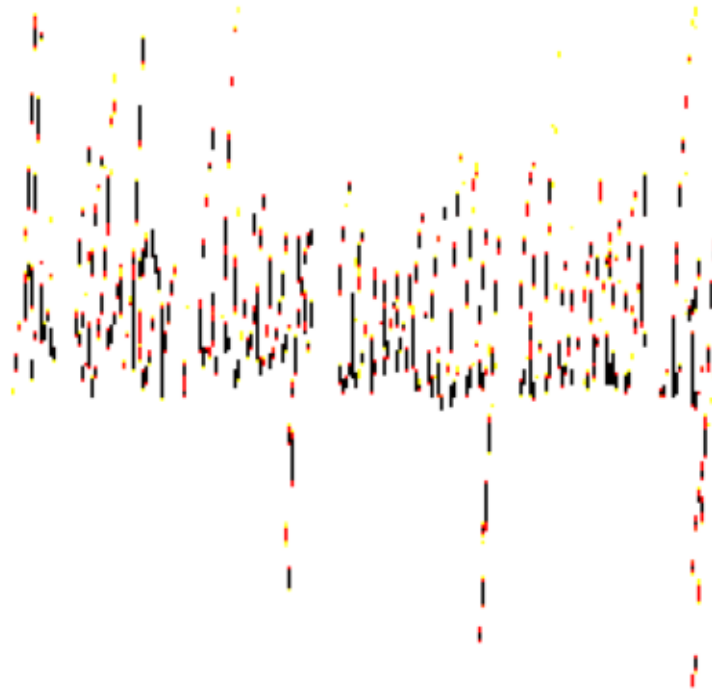Label: 154


```
[18]: base_model = ResNet50(weights='imagenet', include_top=False,␣
      ↪input_shape=(224,224,3))
      base_model.trainable = False  # Freeze base layers initially

      x = base_model.output
      x = GlobalAveragePooling2D()(x)
      x = Dropout(0.5)(x)
      x = Dense(128, activation='relu')(x)
      output = Dense(len(le.classes_), activation='softmax')(x)

      resnet_model = Model(inputs=base_model.input, outputs=output)
      resnet_model.compile(optimizer='adam', loss='categorical_crossentropy',␣
      ↪metrics=['accuracy'])
      resnet_model.summary()

      callbacks = [
          EarlyStopping(monitor='val_loss', patience=5, restore_best_weights=True),
          ReduceLROnPlateau(monitor='val_loss', patience=2, factor=0.5)
      ]
```

Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/resnet/resnet50_weights_tf_dim_ordering_tf_kernels_notop.h5

Model: "functional"

Layer (type)	Output Shape	Param #	Connected to
input_layer (InputLayer)	(None, 224, 224, 3)	0	–
conv1_pad (ZeroPadding2D)	(None, 230, 230, 3)	0	input_layer[0][0]
conv1_conv (Conv2D)	(None, 112, 112, 64)	9,472	conv1_pad[0][0]
conv1_bn (BatchNormalizatio…)	(None, 112, 112, 64)	256	conv1_conv[0][0]
conv1_relu (Activation)	(None, 112, 112, 64)	0	conv1_bn[0][0]
pool1_pad (ZeroPadding2D)	(None, 114, 114, 64)	0	conv1_relu[0][0]
pool1_pool (MaxPooling2D)	(None, 56, 56, 64)	0	pool1_pad[0][0]
conv2_block1_1_conv (Conv2D)	(None, 56, 56, 64)	4,160	pool1_pool[0][0]
conv2_block1_1_bn (BatchNormalizatio…)	(None, 56, 56, 64)	256	conv2_block1_1_c…
conv2_block1_1_relu (Activation)	(None, 56, 56, 64)	0	conv2_block1_1_b…
conv2_block1_2_conv (Conv2D)	(None, 56, 56, 64)	36,928	conv2_block1_1_r…
conv2_block1_2_bn (BatchNormalizatio…)	(None, 56, 56, 64)	256	conv2_block1_2_c…
conv2_block1_2_relu (Activation)	(None, 56, 56, 64)	0	conv2_block1_2_b…
conv2_block1_0_conv	(None, 56, 56,	16,640	pool1_pool[0][0]

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

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(Conv2D)	64)			
conv2_block3_1_bn (BatchNormalizatio…	(None, 56, 56, 64)	256	conv2_block3_1_c…	
conv2_block3_1_relu (Activation)	(None, 56, 56, 64)	0	conv2_block3_1_b…	
conv2_block3_2_conv (Conv2D)	(None, 56, 56, 64)	36,928	conv2_block3_1_r…	
conv2_block3_2_bn (BatchNormalizatio…	(None, 56, 56, 64)	256	conv2_block3_2_c…	
conv2_block3_2_relu (Activation)	(None, 56, 56, 64)	0	conv2_block3_2_b…	
conv2_block3_3_conv (Conv2D)	(None, 56, 56, 256)	16,640	conv2_block3_2_r…	
conv2_block3_3_bn (BatchNormalizatio…	(None, 56, 56, 256)	1,024	conv2_block3_3_c…	
conv2_block3_add (Add)	(None, 56, 56, 256)	0	conv2_block2_out… conv2_block3_3_b…	
conv2_block3_out (Activation)	(None, 56, 56, 256)	0	conv2_block3_add…	
conv3_block1_1_conv (Conv2D)	(None, 28, 28, 128)	32,896	conv2_block3_out…	
conv3_block1_1_bn (BatchNormalizatio…	(None, 28, 28, 128)	512	conv3_block1_1_c…	
conv3_block1_1_relu (Activation)	(None, 28, 28, 128)	0	conv3_block1_1_b…	
conv3_block1_2_conv (Conv2D)	(None, 28, 28, 128)	147,584	conv3_block1_1_r…	
conv3_block1_2_bn (BatchNormalizatio…	(None, 28, 28, 128)	512	conv3_block1_2_c…	
conv3_block1_2_relu (Activation)	(None, 28, 28, 128)	0	conv3_block1_2_b…	
conv3_block1_0_conv	(None, 28, 28,	131,584	conv2_block3_out…	

(Conv2D)	512)		
conv3_block1_3_conv (Conv2D)	(None, 28, 28, 512)	66,048	conv3_block1_2_r…
conv3_block1_0_bn (BatchNormalizatio…	(None, 28, 28, 512)	2,048	conv3_block1_0_c…
conv3_block1_3_bn (BatchNormalizatio…	(None, 28, 28, 512)	2,048	conv3_block1_3_c…
conv3_block1_add (Add)	(None, 28, 28, 512)	0	conv3_block1_0_b… conv3_block1_3_b…
conv3_block1_out (Activation)	(None, 28, 28, 512)	0	conv3_block1_add…
conv3_block2_1_conv (Conv2D)	(None, 28, 28, 128)	65,664	conv3_block1_out…
conv3_block2_1_bn (BatchNormalizatio…	(None, 28, 28, 128)	512	conv3_block2_1_c…
conv3_block2_1_relu (Activation)	(None, 28, 28, 128)	0	conv3_block2_1_b…
conv3_block2_2_conv (Conv2D)	(None, 28, 28, 128)	147,584	conv3_block2_1_r…
conv3_block2_2_bn (BatchNormalizatio…	(None, 28, 28, 128)	512	conv3_block2_2_c…
conv3_block2_2_relu (Activation)	(None, 28, 28, 128)	0	conv3_block2_2_b…
conv3_block2_3_conv (Conv2D)	(None, 28, 28, 512)	66,048	conv3_block2_2_r…
conv3_block2_3_bn (BatchNormalizatio…	(None, 28, 28, 512)	2,048	conv3_block2_3_c…
conv3_block2_add (Add)	(None, 28, 28, 512)	0	conv3_block1_out… conv3_block2_3_b…
conv3_block2_out (Activation)	(None, 28, 28, 512)	0	conv3_block2_add…
conv3_block3_1_conv	(None, 28, 28,	65,664	conv3_block2_out…

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

(Conv2D)	512)		
conv3_block4_3_bn (BatchNormalizatio…	(None, 28, 28, 512)	2,048	conv3_block4_3_c…
conv3_block4_add (Add)	(None, 28, 28, 512)	0	conv3_block3_out… conv3_block4_3_b…
conv3_block4_out (Activation)	(None, 28, 28, 512)	0	conv3_block4_add…
conv4_block1_1_conv (Conv2D)	(None, 14, 14, 256)	131,328	conv3_block4_out…
conv4_block1_1_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block1_1_c…
conv4_block1_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_block1_1_b…
conv4_block1_2_conv (Conv2D)	(None, 14, 14, 256)	590,080	conv4_block1_1_r…
conv4_block1_2_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block1_2_c…
conv4_block1_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_block1_2_b…
conv4_block1_0_conv (Conv2D)	(None, 14, 14, 1024)	525,312	conv3_block4_out…
conv4_block1_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_block1_2_r…
conv4_block1_0_bn (BatchNormalizatio…	(None, 14, 14, 1024)	4,096	conv4_block1_0_c…
conv4_block1_3_bn (BatchNormalizatio…	(None, 14, 14, 1024)	4,096	conv4_block1_3_c…
conv4_block1_add (Add)	(None, 14, 14, 1024)	0	conv4_block1_0_b… conv4_block1_3_b…
conv4_block1_out (Activation)	(None, 14, 14, 1024)	0	conv4_block1_add…
conv4_block2_1_conv	(None, 14, 14,	262,400	conv4_block1_out…

(Conv2D)	256)		
conv4_block2_1_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block2_1_c…
conv4_block2_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_block2_1_b…
conv4_block2_2_conv (Conv2D)	(None, 14, 14, 256)	590,080	conv4_block2_1_r…
conv4_block2_2_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block2_2_c…
conv4_block2_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_block2_2_b…
conv4_block2_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_block2_2_r…
conv4_block2_3_bn (BatchNormalizatio…	(None, 14, 14, 1024)	4,096	conv4_block2_3_c…
conv4_block2_add (Add)	(None, 14, 14, 1024)	0	conv4_block1_out… conv4_block2_3_b…
conv4_block2_out (Activation)	(None, 14, 14, 1024)	0	conv4_block2_add…
conv4_block3_1_conv (Conv2D)	(None, 14, 14, 256)	262,400	conv4_block2_out…
conv4_block3_1_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block3_1_c…
conv4_block3_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_block3_1_b…
conv4_block3_2_conv (Conv2D)	(None, 14, 14, 256)	590,080	conv4_block3_1_r…
conv4_block3_2_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block3_2_c…
conv4_block3_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_block3_2_b…
conv4_block3_3_conv	(None, 14, 14,	263,168	conv4_block3_2_r…

Layer	Output Shape	Param #	Connected to
(Conv2D)	1024)		
conv4_block3_3_bn (BatchNormalizatio…	(None, 14, 14, 1024)	4,096	conv4_block3_3_c…
conv4_block3_add (Add)	(None, 14, 14, 1024)	0	conv4_block2_out… conv4_block3_3_b…
conv4_block3_out (Activation)	(None, 14, 14, 1024)	0	conv4_block3_add…
conv4_block4_1_conv (Conv2D)	(None, 14, 14, 256)	262,400	conv4_block3_out…
conv4_block4_1_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block4_1_c…
conv4_block4_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_block4_1_b…
conv4_block4_2_conv (Conv2D)	(None, 14, 14, 256)	590,080	conv4_block4_1_r…
conv4_block4_2_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block4_2_c…
conv4_block4_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_block4_2_b…
conv4_block4_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_block4_2_r…
conv4_block4_3_bn (BatchNormalizatio…	(None, 14, 14, 1024)	4,096	conv4_block4_3_c…
conv4_block4_add (Add)	(None, 14, 14, 1024)	0	conv4_block3_out… conv4_block4_3_b…
conv4_block4_out (Activation)	(None, 14, 14, 1024)	0	conv4_block4_add…
conv4_block5_1_conv (Conv2D)	(None, 14, 14, 256)	262,400	conv4_block4_out…
conv4_block5_1_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block5_1_c…
conv4_block5_1_relu	(None, 14, 14,	0	conv4_block5_1_b…

(Activation)	256)			
conv4_block5_2_conv (Conv2D)	(None, 14, 14, 256)	590,080	conv4_block5_1_r…	
conv4_block5_2_bn (BatchNormalizatio…)	(None, 14, 14, 256)	1,024	conv4_block5_2_c…	
conv4_block5_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_block5_2_b…	
conv4_block5_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_block5_2_r…	
conv4_block5_3_bn (BatchNormalizatio…)	(None, 14, 14, 1024)	4,096	conv4_block5_3_c…	
conv4_block5_add (Add)	(None, 14, 14, 1024)	0	conv4_block4_out… conv4_block5_3_b…	
conv4_block5_out (Activation)	(None, 14, 14, 1024)	0	conv4_block5_add…	
conv4_block6_1_conv (Conv2D)	(None, 14, 14, 256)	262,400	conv4_block5_out…	
conv4_block6_1_bn (BatchNormalizatio…)	(None, 14, 14, 256)	1,024	conv4_block6_1_c…	
conv4_block6_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_block6_1_b…	
conv4_block6_2_conv (Conv2D)	(None, 14, 14, 256)	590,080	conv4_block6_1_r…	
conv4_block6_2_bn (BatchNormalizatio…)	(None, 14, 14, 256)	1,024	conv4_block6_2_c…	
conv4_block6_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_block6_2_b…	
conv4_block6_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_block6_2_r…	
conv4_block6_3_bn (BatchNormalizatio…)	(None, 14, 14, 1024)	4,096	conv4_block6_3_c…	
conv4_block6_add	(None, 14, 14,	0	conv4_block5_out…	

(Add)	1024)		conv4_block6_3_b…
conv4_block6_out (Activation)	(None, 14, 14, 1024)	0	conv4_block6_add…
conv5_block1_1_conv (Conv2D)	(None, 7, 7, 512)	524,800	conv4_block6_out…
conv5_block1_1_bn (BatchNormalizatio…)	(None, 7, 7, 512)	2,048	conv5_block1_1_c…
conv5_block1_1_relu (Activation)	(None, 7, 7, 512)	0	conv5_block1_1_b…
conv5_block1_2_conv (Conv2D)	(None, 7, 7, 512)	2,359,808	conv5_block1_1_r…
conv5_block1_2_bn (BatchNormalizatio…)	(None, 7, 7, 512)	2,048	conv5_block1_2_c…
conv5_block1_2_relu (Activation)	(None, 7, 7, 512)	0	conv5_block1_2_b…
conv5_block1_0_conv (Conv2D)	(None, 7, 7, 2048)	2,099,200	conv4_block6_out…
conv5_block1_3_conv (Conv2D)	(None, 7, 7, 2048)	1,050,624	conv5_block1_2_r…
conv5_block1_0_bn (BatchNormalizatio…)	(None, 7, 7, 2048)	8,192	conv5_block1_0_c…
conv5_block1_3_bn (BatchNormalizatio…)	(None, 7, 7, 2048)	8,192	conv5_block1_3_c…
conv5_block1_add (Add)	(None, 7, 7, 2048)	0	conv5_block1_0_b… conv5_block1_3_b…
conv5_block1_out (Activation)	(None, 7, 7, 2048)	0	conv5_block1_add…
conv5_block2_1_conv (Conv2D)	(None, 7, 7, 512)	1,049,088	conv5_block1_out…
conv5_block2_1_bn (BatchNormalizatio…)	(None, 7, 7, 512)	2,048	conv5_block2_1_c…
conv5_block2_1_relu	(None, 7, 7, 512)	0	conv5_block2_1_b…

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(Activation)

Layer	Output Shape	Param #	Connected to
conv5_block2_2_conv (Conv2D)	(None, 7, 7, 512)	2,359,808	conv5_block2_1_r…
conv5_block2_2_bn (BatchNormalizatio…)	(None, 7, 7, 512)	2,048	conv5_block2_2_c…
conv5_block2_2_relu (Activation)	(None, 7, 7, 512)	0	conv5_block2_2_b…
conv5_block2_3_conv (Conv2D)	(None, 7, 7, 2048)	1,050,624	conv5_block2_2_r…
conv5_block2_3_bn (BatchNormalizatio…)	(None, 7, 7, 2048)	8,192	conv5_block2_3_c…
conv5_block2_add (Add)	(None, 7, 7, 2048)	0	conv5_block1_out… conv5_block2_3_b…
conv5_block2_out (Activation)	(None, 7, 7, 2048)	0	conv5_block2_add…
conv5_block3_1_conv (Conv2D)	(None, 7, 7, 512)	1,049,088	conv5_block2_out…
conv5_block3_1_bn (BatchNormalizatio…)	(None, 7, 7, 512)	2,048	conv5_block3_1_c…
conv5_block3_1_relu (Activation)	(None, 7, 7, 512)	0	conv5_block3_1_b…
conv5_block3_2_conv (Conv2D)	(None, 7, 7, 512)	2,359,808	conv5_block3_1_r…
conv5_block3_2_bn (BatchNormalizatio…)	(None, 7, 7, 512)	2,048	conv5_block3_2_c…
conv5_block3_2_relu (Activation)	(None, 7, 7, 512)	0	conv5_block3_2_b…
conv5_block3_3_conv (Conv2D)	(None, 7, 7, 2048)	1,050,624	conv5_block3_2_r…
conv5_block3_3_bn (BatchNormalizatio…)	(None, 7, 7, 2048)	8,192	conv5_block3_3_c…
conv5_block3_add	(None, 7, 7,	0	conv5_block2_out…

(Add)	2048)		conv5_block3_3_b…
conv5_block3_out (Activation)	(None, 7, 7, 2048)	0	conv5_block3_add…
global_average_poo… (GlobalAveragePool…	(None, 2048)	0	conv5_block3_out…
dropout (Dropout)	(None, 2048)	0	global_average_p…
dense (Dense)	(None, 128)	262,272	dropout[0][0]
dense_1 (Dense)	(None, 10)	1,290	dense[0][0]

Total params: 23,851,274 (90.99 MB)

Trainable params: 263,562 (1.01 MB)

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

```
[19]: history = resnet_model.fit(
          X_train, y_train,
          validation_data=(X_test, y_test),
          batch_size=32,
          epochs=15,
          callbacks=callbacks
      )
```

```
Epoch 1/15
45/45              31s 383ms/step -
accuracy: 0.4446 - loss: 1.8405 - val_accuracy: 0.7827 - val_loss: 0.7274 -
learning_rate: 0.0010
Epoch 2/15
45/45              5s 101ms/step -
accuracy: 0.7313 - loss: 0.7936 - val_accuracy: 0.8914 - val_loss: 0.3952 -
learning_rate: 0.0010
Epoch 3/15
45/45              5s 101ms/step -
accuracy: 0.8180 - loss: 0.5350 - val_accuracy: 0.9164 - val_loss: 0.3032 -
learning_rate: 0.0010
Epoch 4/15
45/45              5s 103ms/step -
accuracy: 0.8611 - loss: 0.3947 - val_accuracy: 0.9248 - val_loss: 0.2602 -
learning_rate: 0.0010
```

```
Epoch 5/15
45/45                5s 102ms/step -
accuracy: 0.8976 - loss: 0.3119 - val_accuracy: 0.9192 - val_loss: 0.2476 -
learning_rate: 0.0010
Epoch 6/15
45/45                6s 113ms/step -
accuracy: 0.9065 - loss: 0.2968 - val_accuracy: 0.9359 - val_loss: 0.2276 -
learning_rate: 0.0010
Epoch 7/15
45/45                5s 111ms/step -
accuracy: 0.9064 - loss: 0.2775 - val_accuracy: 0.9499 - val_loss: 0.1921 -
learning_rate: 0.0010
Epoch 8/15
45/45                5s 106ms/step -
accuracy: 0.9322 - loss: 0.1954 - val_accuracy: 0.9499 - val_loss: 0.1894 -
learning_rate: 0.0010
Epoch 9/15
45/45                5s 109ms/step -
accuracy: 0.9431 - loss: 0.1825 - val_accuracy: 0.9415 - val_loss: 0.2185 -
learning_rate: 0.0010
Epoch 10/15
45/45                5s 101ms/step -
accuracy: 0.9364 - loss: 0.1771 - val_accuracy: 0.9331 - val_loss: 0.2220 -
learning_rate: 0.0010
Epoch 11/15
45/45                5s 105ms/step -
accuracy: 0.9494 - loss: 0.1420 - val_accuracy: 0.9582 - val_loss: 0.1555 -
learning_rate: 5.0000e-04
Epoch 12/15
45/45                5s 110ms/step -
accuracy: 0.9557 - loss: 0.1369 - val_accuracy: 0.9526 - val_loss: 0.1759 -
learning_rate: 5.0000e-04
Epoch 13/15
45/45                5s 113ms/step -
accuracy: 0.9537 - loss: 0.1389 - val_accuracy: 0.9526 - val_loss: 0.1870 -
learning_rate: 5.0000e-04
Epoch 14/15
45/45                5s 111ms/step -
accuracy: 0.9613 - loss: 0.1226 - val_accuracy: 0.9554 - val_loss: 0.1752 -
learning_rate: 2.5000e-04
Epoch 15/15
45/45                5s 116ms/step -
accuracy: 0.9724 - loss: 0.0929 - val_accuracy: 0.9666 - val_loss: 0.1462 -
learning_rate: 2.5000e-04
```
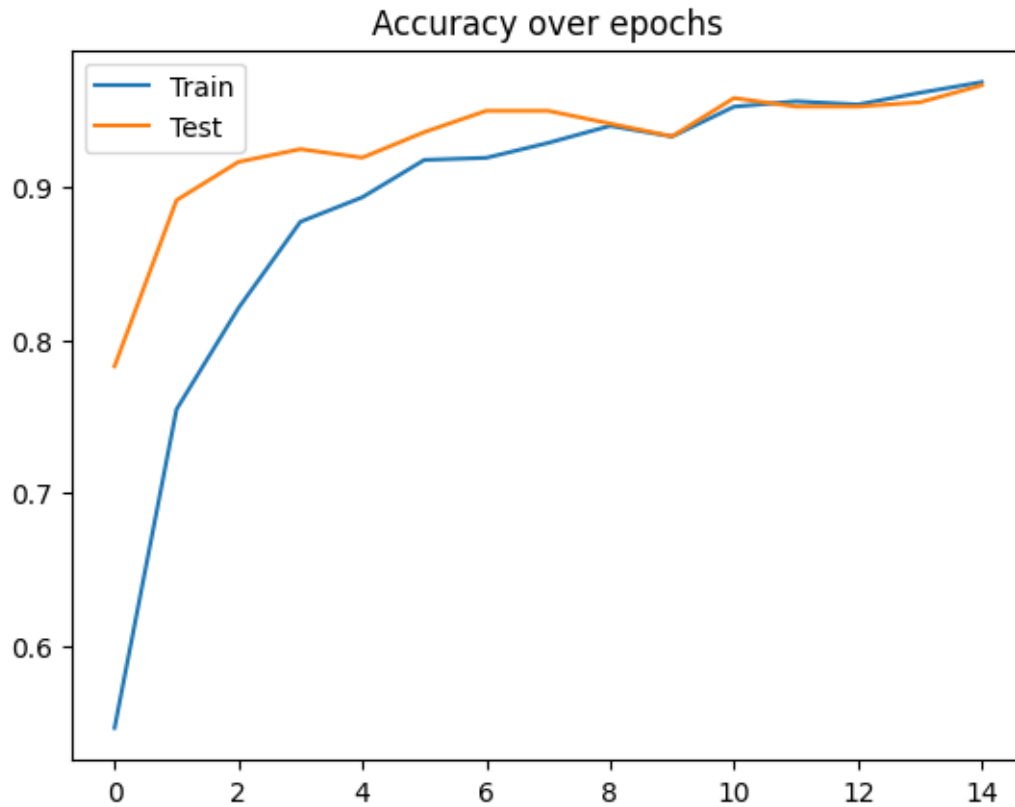
```python
[20]: import matplotlib.pyplot as plt
      plt.plot(history.history['accuracy'], label='Train')
```

```
plt.plot(history.history['val_accuracy'], label='Test')
plt.title('Accuracy over epochs')
plt.legend()
plt.show()
```

Accuracy over epochs


```
[21]: import matplotlib.pyplot as plt
plt.plot(history.history['loss'], label='Train')
plt.plot(history.history['val_loss'], label='Test')
plt.title('Loss over epochs')
plt.legend()
plt.show()
```

Loss over epochs
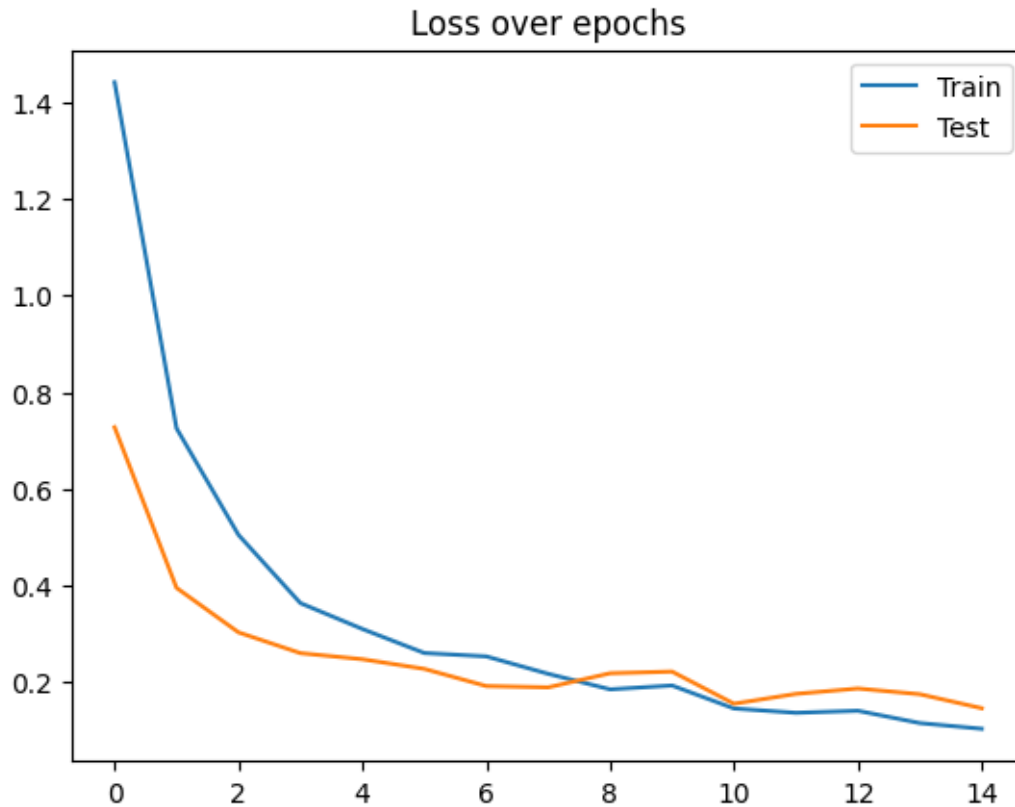
```
[22]: resnet_model.save("/kaggle/resnet_model.keras")
```

```
[23]: from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
      import numpy as np

      y_pred = resnet_model.predict(X_test)
      y_pred_labels = np.argmax(y_pred, axis=1)
      y_true_labels = np.argmax(y_test, axis=1)

      cm = confusion_matrix(y_true_labels, y_pred_labels)
      disp = ConfusionMatrixDisplay(cm, display_labels=le.classes_)
      disp.plot(cmap='viridis', xticks_rotation=90)
```

```
12/12                8s 393ms/step
```

```
[23]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at
      0x7abc62514710>
```
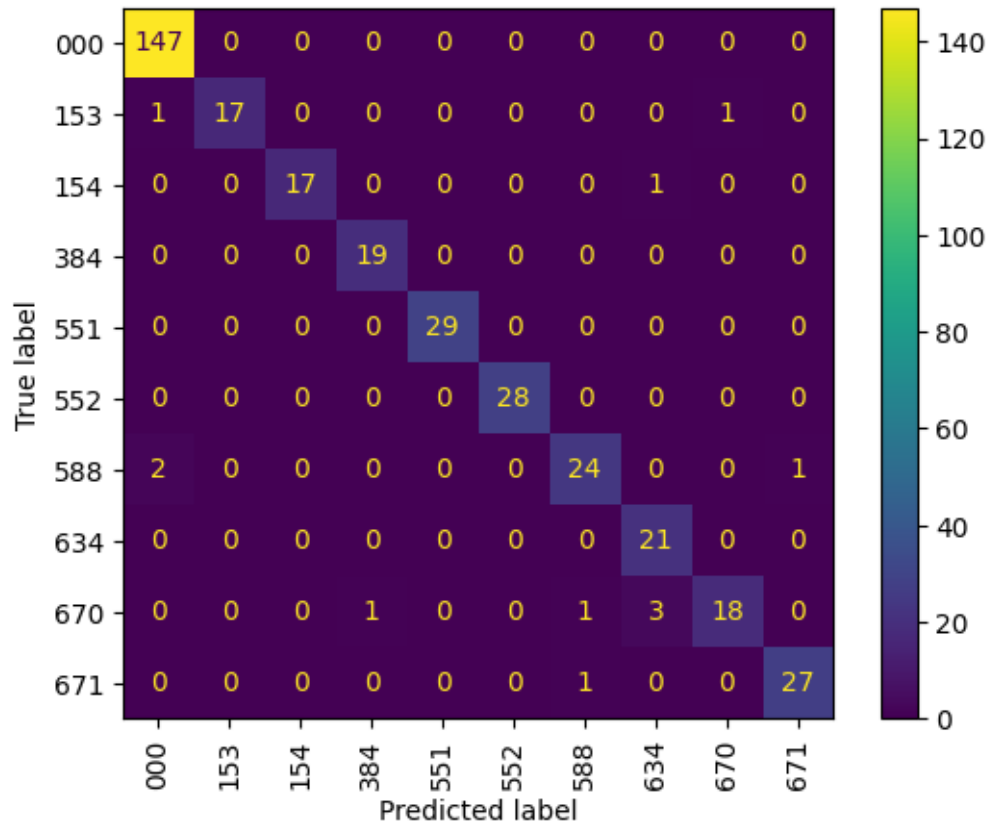
```
[24]: preds = resnet_model.predict(X_test)
      for i in range(5):
          plt.imshow(X_test[i].squeeze(), cmap='gray')
          true_label = le.inverse_transform([np.argmax(y_test[i])])[0]
          pred_label = le.inverse_transform([np.argmax(preds[i])])[0]
          plt.title(f"True: {true_label} | Pred: {pred_label}")
          plt.axis('off')
          plt.show()
```

12/12   1s 80ms/step

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
[-72.68..151.061].

True: 671 | Pred: 671
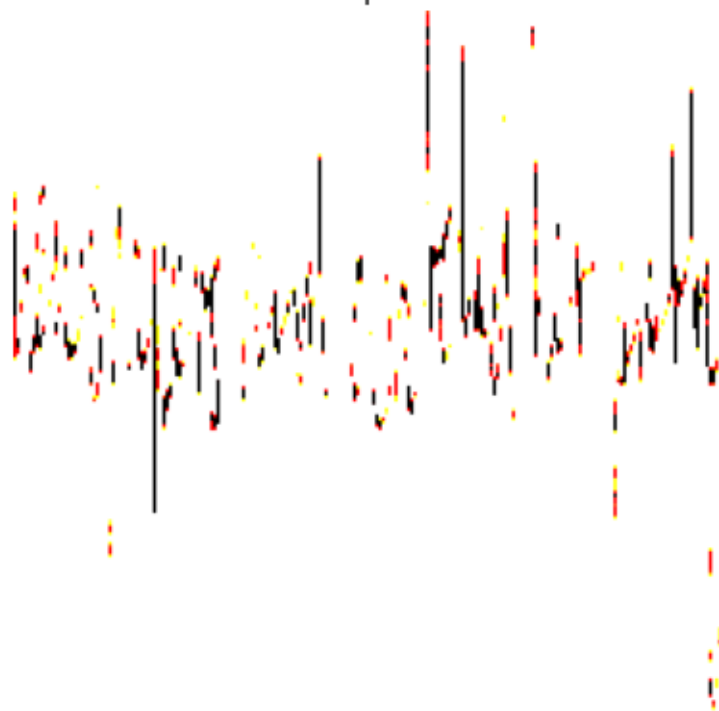
WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
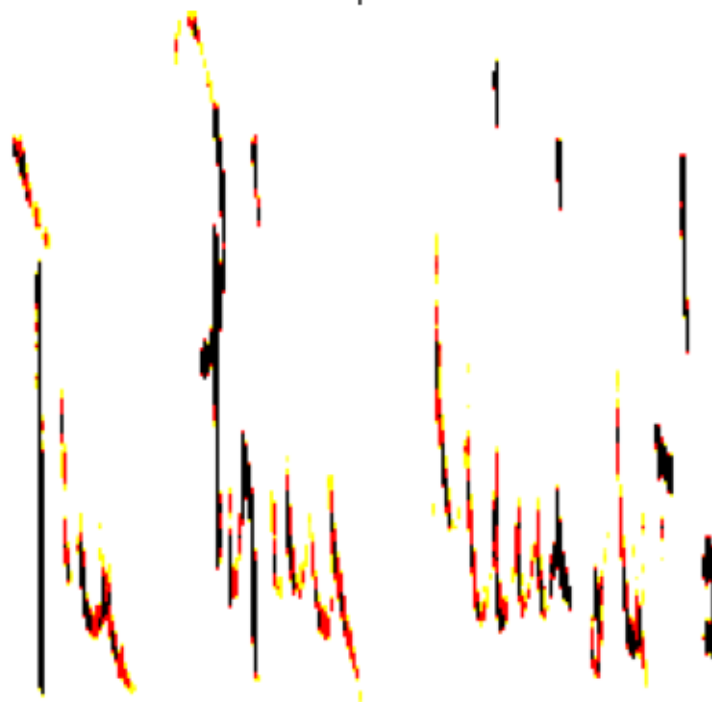[-89.68..151.061].

True: 670 | Pred: 670
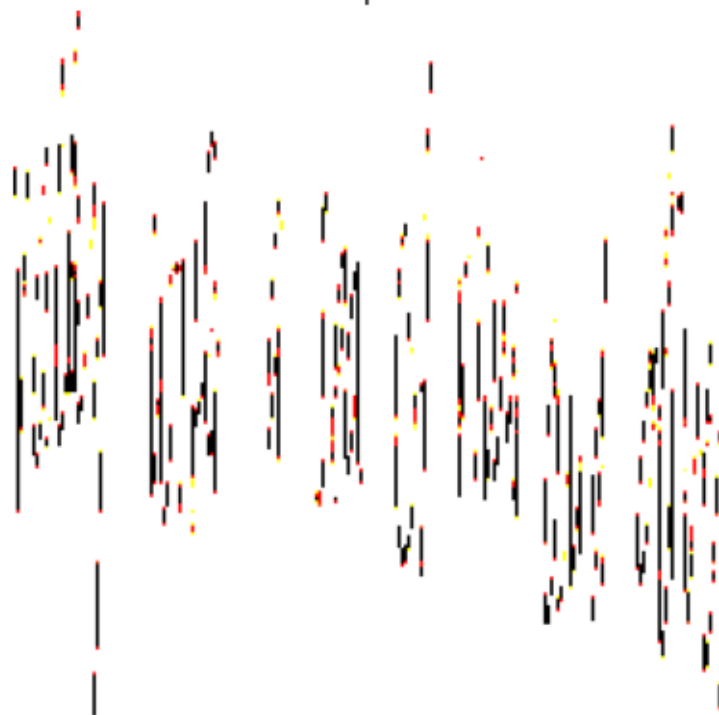
WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
[-74.68..151.061].

True: 000 | Pred: 000

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). Got range [-61.68..151.061].

True: 671 | Pred: 671

WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
RGB data ([0..1] for floats or [0..255] for integers). Got range
[-100.68..151.061].