Codes for the Model

```
import numpy as np
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Activation, Dense, Flatten, BatchNormalization, Conv2D,
MaxPool2D
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.metrics import categorical_crossentropy
from tensorflow.keras.preprocessing.image import ImageDataGenerator
import itertools
import os
import shutil
import random
import glob
import matplotlib.pyplot as plt
import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)
%matplotlib inline


train_path = r"C:\Users\kemi\Desktop\opencv\aug\data\train"
valid_path = r"C:\Users\kemi\Desktop\opencv\aug\data\valid"
test_path = r"C:\Users\kemi\Desktop\opencv\aug\data\test"


train_batches =
ImageDataGenerator(preprocessing_function=tf.keras.applications.vgg16.preprocess_input) \
    .flow_from_directory(directory=train_path, target_size=(224,224),
classes=['looselyChained', 'tightlyChained', 'unchained'], batch_size=10)
valid_batches =
ImageDataGenerator(preprocessing_function=tf.keras.applications.vgg16.preprocess_input) \
    .flow_from_directory(directory=valid_path, target_size=(224,224),
classes=['looselyChained', 'tightlyChained', 'unchained'], batch_size=10)
test_batches =
ImageDataGenerator(preprocessing_function=tf.keras.applications.vgg16.preprocess_input) \
    .flow_from_directory(directory=test_path, target_size=(224,224),
classes=['looselyChained', 'tightlyChained', 'unchained'], batch_size=10, shuffle=False
```

**Result:**

```
Found 3000 images belonging to 3 classes.
Found 600 images belonging to 3 classes.
Found 300 images belonging to 3 classes.
```

```
imgs, labels = next(train_batches)


def plotImages(images_arr):
    fig, axes = plt.subplots(1, 10, figsize=(20,20))
    axes = axes.flatten()
    for img, ax in zip( images_arr, axes):
    ax.imshow(img)
    ax.axis('off')
    plt.tight_layout()
    plt.show()


plotImages(imgs)
print(labels)
```

**Result:**

```
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1]
for floats or [0..255] for integers).
```

```
[[1. 0. 0.]
 [1. 0. 0.]
 [0. 0. 1.]
```

```
 [0. 1. 0.]
 [1. 0. 0.]
 [1. 0. 0.]
 [0. 0. 1.]
 [0. 1. 0.]
 [0. 1. 0.]
 [0. 1. 0.]]
```

#build a fine-tuned pre-trained model

mobile = tf.keras.applications.mobilenet.MobileNet()
mobile.summary()

**Result:**

```
Model: "mobilenet_1.00_224"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         [(None, 224, 224, 3)]     0
_________________________________________________________________
conv1 (Conv2D)               (None, 112, 112, 32)      864
_________________________________________________________________
conv1_bn (BatchNormalization (None, 112, 112, 32)      128
_________________________________________________________________
conv1_relu (ReLU)            (None, 112, 112, 32)      0
_________________________________________________________________
conv_dw_1 (DepthwiseConv2D)  (None, 112, 112, 32)      288
_________________________________________________________________
conv_dw_1_bn (BatchNormaliza (None, 112, 112, 32)      128
_________________________________________________________________
conv_dw_1_relu (ReLU)        (None, 112, 112, 32)      0
_________________________________________________________________
conv_pw_1 (Conv2D)           (None, 112, 112, 64)      2048
_________________________________________________________________
conv_pw_1_bn (BatchNormaliza (None, 112, 112, 64)      256
_________________________________________________________________
conv_pw_1_relu (ReLU)        (None, 112, 112, 64)      0
_________________________________________________________________
conv_pad_2 (ZeroPadding2D)   (None, 113, 113, 64)      0
_________________________________________________________________
conv_dw_2 (DepthwiseConv2D)  (None, 56, 56, 64)        576
_________________________________________________________________
conv_dw_2_bn (BatchNormaliza (None, 56, 56, 64)        256
_________________________________________________________________
```

```
conv_dw_2_relu (ReLU)        (None, 56, 56, 64)        0
_________________________________________________________________
conv_pw_2 (Conv2D)           (None, 56, 56, 128)       8192
_________________________________________________________________
conv_pw_2_bn (BatchNormaliza (None, 56, 56, 128)       512
_________________________________________________________________
conv_pw_2_relu (ReLU)        (None, 56, 56, 128)       0
_________________________________________________________________
conv_dw_3 (DepthwiseConv2D)  (None, 56, 56, 128)       1152
_________________________________________________________________
conv_dw_3_bn (BatchNormaliza (None, 56, 56, 128)       512
_________________________________________________________________
conv_dw_3_relu (ReLU)        (None, 56, 56, 128)       0
_________________________________________________________________
conv_pw_3 (Conv2D)           (None, 56, 56, 128)       16384
_________________________________________________________________
conv_pw_3_bn (BatchNormaliza (None, 56, 56, 128)       512
_________________________________________________________________
conv_pw_3_relu (ReLU)        (None, 56, 56, 128)       0
_________________________________________________________________
conv_pad_4 (ZeroPadding2D)   (None, 57, 57, 128)       0
_________________________________________________________________
conv_dw_4 (DepthwiseConv2D)  (None, 28, 28, 128)       1152
_________________________________________________________________
conv_dw_4_bn (BatchNormaliza (None, 28, 28, 128)       512
_________________________________________________________________
conv_dw_4_relu (ReLU)        (None, 28, 28, 128)       0
_________________________________________________________________
conv_pw_4 (Conv2D)           (None, 28, 28, 256)       32768
_________________________________________________________________
conv_pw_4_bn (BatchNormaliza (None, 28, 28, 256)       1024
_________________________________________________________________
conv_pw_4_relu (ReLU)        (None, 28, 28, 256)       0
_________________________________________________________________
conv_dw_5 (DepthwiseConv2D)  (None, 28, 28, 256)       2304
_________________________________________________________________
conv_dw_5_bn (BatchNormaliza (None, 28, 28, 256)       1024
_________________________________________________________________
conv_dw_5_relu (ReLU)        (None, 28, 28, 256)       0
_________________________________________________________________
conv_pw_5 (Conv2D)           (None, 28, 28, 256)       65536
_________________________________________________________________
conv_pw_5_bn (BatchNormaliza (None, 28, 28, 256)       1024
_________________________________________________________________
conv_pw_5_relu (ReLU)        (None, 28, 28, 256)       0
_________________________________________________________________
conv_pad_6 (ZeroPadding2D)   (None, 29, 29, 256)       0
```

```
_________________________________________________________________
conv_dw_6 (DepthwiseConv2D)  (None, 14, 14, 256)       2304
_________________________________________________________________
conv_dw_6_bn (BatchNormaliza (None, 14, 14, 256)       1024
_________________________________________________________________
conv_dw_6_relu (ReLU)        (None, 14, 14, 256)       0
_________________________________________________________________
conv_pw_6 (Conv2D)           (None, 14, 14, 512)       131072
_________________________________________________________________
conv_pw_6_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_pw_6_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_dw_7 (DepthwiseConv2D)  (None, 14, 14, 512)       4608
_________________________________________________________________
conv_dw_7_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_dw_7_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_pw_7 (Conv2D)           (None, 14, 14, 512)       262144
_________________________________________________________________
conv_pw_7_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_pw_7_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_dw_8 (DepthwiseConv2D)  (None, 14, 14, 512)       4608
_________________________________________________________________
conv_dw_8_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_dw_8_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_pw_8 (Conv2D)           (None, 14, 14, 512)       262144
_________________________________________________________________
conv_pw_8_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_pw_8_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_dw_9 (DepthwiseConv2D)  (None, 14, 14, 512)       4608
_________________________________________________________________
conv_dw_9_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_dw_9_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_pw_9 (Conv2D)           (None, 14, 14, 512)       262144
_________________________________________________________________
conv_pw_9_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
```

```
conv_pw_9_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_dw_10 (DepthwiseConv2D) (None, 14, 14, 512)       4608
_________________________________________________________________
conv_dw_10_bn (BatchNormaliz (None, 14, 14, 512)       2048
_________________________________________________________________
conv_dw_10_relu (ReLU)       (None, 14, 14, 512)       0
_________________________________________________________________
conv_pw_10 (Conv2D)          (None, 14, 14, 512)       262144
_________________________________________________________________
conv_pw_10_bn (BatchNormaliz (None, 14, 14, 512)       2048
_________________________________________________________________
conv_pw_10_relu (ReLU)       (None, 14, 14, 512)       0
_________________________________________________________________
conv_dw_11 (DepthwiseConv2D) (None, 14, 14, 512)       4608
_________________________________________________________________
conv_dw_11_bn (BatchNormaliz (None, 14, 14, 512)       2048
_________________________________________________________________
conv_dw_11_relu (ReLU)       (None, 14, 14, 512)       0
_________________________________________________________________
conv_pw_11 (Conv2D)          (None, 14, 14, 512)       262144
_________________________________________________________________
conv_pw_11_bn (BatchNormaliz (None, 14, 14, 512)       2048
_________________________________________________________________
conv_pw_11_relu (ReLU)       (None, 14, 14, 512)       0
_________________________________________________________________
conv_pad_12 (ZeroPadding2D)  (None, 15, 15, 512)       0
_________________________________________________________________
conv_dw_12 (DepthwiseConv2D) (None, 7, 7, 512)         4608
_________________________________________________________________
conv_dw_12_bn (BatchNormaliz (None, 7, 7, 512)         2048
_________________________________________________________________
conv_dw_12_relu (ReLU)       (None, 7, 7, 512)         0
_________________________________________________________________
conv_pw_12 (Conv2D)          (None, 7, 7, 1024)        524288
_________________________________________________________________
conv_pw_12_bn (BatchNormaliz (None, 7, 7, 1024)        4096
_________________________________________________________________
conv_pw_12_relu (ReLU)       (None, 7, 7, 1024)        0
_________________________________________________________________
conv_dw_13 (DepthwiseConv2D) (None, 7, 7, 1024)        9216
_________________________________________________________________
conv_dw_13_bn (BatchNormaliz (None, 7, 7, 1024)        4096
_________________________________________________________________
conv_dw_13_relu (ReLU)       (None, 7, 7, 1024)        0
_________________________________________________________________
conv_pw_13 (Conv2D)          (None, 7, 7, 1024)        1048576
```

```
_________________________________________________________________
conv_pw_13_bn (BatchNormaliz (None, 7, 7, 1024)        4096
_________________________________________________________________
conv_pw_13_relu (ReLU)       (None, 7, 7, 1024)        0
_________________________________________________________________
global_average_pooling2d_1 ( (None, 1024)              0
_________________________________________________________________
reshape_1 (Reshape)          (None, 1, 1, 1024)        0
_________________________________________________________________
dropout (Dropout)            (None, 1, 1, 1024)        0
_________________________________________________________________
conv_preds (Conv2D)          (None, 1, 1, 1000)        1025000
_________________________________________________________________
reshape_2 (Reshape)          (None, 1000)              0
_________________________________________________________________
predictions (Activation)     (None, 1000)              0
=================================================================
Total params: 4,253,864
Trainable params: 4,231,976
Non-trainable params: 21,888
_________________________________________________________________
```

```
x = mobile.layers[-6].output
```

```
output = Dense(units=3, activation='softmax')(x)
```

```
from tensorflow.keras.models import Model
model = Model(inputs=mobile.input, outputs=output)
```

```
for layer in model.layers[:-23]:
        layer.trainable = True
```

```
model.summary()
```

Result:

```
Model: "model_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         [(None, 224, 224, 3)]     0
```

| | | |
|---|---|---|
| conv1 (Conv2D) | (None, 112, 112, 32) | 864 |
| conv1_bn (BatchNormalization | (None, 112, 112, 32) | 128 |
| conv1_relu (ReLU) | (None, 112, 112, 32) | 0 |
| conv_dw_1 (DepthwiseConv2D) | (None, 112, 112, 32) | 288 |
| conv_dw_1_bn (BatchNormaliza | (None, 112, 112, 32) | 128 |
| conv_dw_1_relu (ReLU) | (None, 112, 112, 32) | 0 |
| conv_pw_1 (Conv2D) | (None, 112, 112, 64) | 2048 |
| conv_pw_1_bn (BatchNormaliza | (None, 112, 112, 64) | 256 |
| conv_pw_1_relu (ReLU) | (None, 112, 112, 64) | 0 |
| conv_pad_2 (ZeroPadding2D) | (None, 113, 113, 64) | 0 |
| conv_dw_2 (DepthwiseConv2D) | (None, 56, 56, 64) | 576 |
| conv_dw_2_bn (BatchNormaliza | (None, 56, 56, 64) | 256 |
| conv_dw_2_relu (ReLU) | (None, 56, 56, 64) | 0 |
| conv_pw_2 (Conv2D) | (None, 56, 56, 128) | 8192 |
| conv_pw_2_bn (BatchNormaliza | (None, 56, 56, 128) | 512 |
| conv_pw_2_relu (ReLU) | (None, 56, 56, 128) | 0 |
| conv_dw_3 (DepthwiseConv2D) | (None, 56, 56, 128) | 1152 |
| conv_dw_3_bn (BatchNormaliza | (None, 56, 56, 128) | 512 |
| conv_dw_3_relu (ReLU) | (None, 56, 56, 128) | 0 |
| conv_pw_3 (Conv2D) | (None, 56, 56, 128) | 16384 |
| conv_pw_3_bn (BatchNormaliza | (None, 56, 56, 128) | 512 |
| conv_pw_3_relu (ReLU) | (None, 56, 56, 128) | 0 |
| conv_pad_4 (ZeroPadding2D) | (None, 57, 57, 128) | 0 |

| | | |
|---|---|---|
| conv_dw_4 (DepthwiseConv2D) | (None, 28, 28, 128) | 1152 |
| conv_dw_4_bn (BatchNormaliza | (None, 28, 28, 128) | 512 |
| conv_dw_4_relu (ReLU) | (None, 28, 28, 128) | 0 |
| conv_pw_4 (Conv2D) | (None, 28, 28, 256) | 32768 |
| conv_pw_4_bn (BatchNormaliza | (None, 28, 28, 256) | 1024 |
| conv_pw_4_relu (ReLU) | (None, 28, 28, 256) | 0 |
| conv_dw_5 (DepthwiseConv2D) | (None, 28, 28, 256) | 2304 |
| conv_dw_5_bn (BatchNormaliza | (None, 28, 28, 256) | 1024 |
| conv_dw_5_relu (ReLU) | (None, 28, 28, 256) | 0 |
| conv_pw_5 (Conv2D) | (None, 28, 28, 256) | 65536 |
| conv_pw_5_bn (BatchNormaliza | (None, 28, 28, 256) | 1024 |
| conv_pw_5_relu (ReLU) | (None, 28, 28, 256) | 0 |
| conv_pad_6 (ZeroPadding2D) | (None, 29, 29, 256) | 0 |
| conv_dw_6 (DepthwiseConv2D) | (None, 14, 14, 256) | 2304 |
| conv_dw_6_bn (BatchNormaliza | (None, 14, 14, 256) | 1024 |
| conv_dw_6_relu (ReLU) | (None, 14, 14, 256) | 0 |
| conv_pw_6 (Conv2D) | (None, 14, 14, 512) | 131072 |
| conv_pw_6_bn (BatchNormaliza | (None, 14, 14, 512) | 2048 |
| conv_pw_6_relu (ReLU) | (None, 14, 14, 512) | 0 |
| conv_dw_7 (DepthwiseConv2D) | (None, 14, 14, 512) | 4608 |
| conv_dw_7_bn (BatchNormaliza | (None, 14, 14, 512) | 2048 |
| conv_dw_7_relu (ReLU) | (None, 14, 14, 512) | 0 |
| conv_pw_7 (Conv2D) | (None, 14, 14, 512) | 262144 |
| conv_pw_7_bn (BatchNormaliza | (None, 14, 14, 512) | 2048 |

```
_________________________________________________________________
conv_pw_7_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_dw_8 (DepthwiseConv2D)  (None, 14, 14, 512)       4608
_________________________________________________________________
conv_dw_8_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_dw_8_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_pw_8 (Conv2D)           (None, 14, 14, 512)       262144
_________________________________________________________________
conv_pw_8_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_pw_8_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_dw_9 (DepthwiseConv2D)  (None, 14, 14, 512)       4608
_________________________________________________________________
conv_dw_9_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_dw_9_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_pw_9 (Conv2D)           (None, 14, 14, 512)       262144
_________________________________________________________________
conv_pw_9_bn (BatchNormaliza (None, 14, 14, 512)       2048
_________________________________________________________________
conv_pw_9_relu (ReLU)        (None, 14, 14, 512)       0
_________________________________________________________________
conv_dw_10 (DepthwiseConv2D) (None, 14, 14, 512)       4608
_________________________________________________________________
conv_dw_10_bn (BatchNormaliz (None, 14, 14, 512)       2048
_________________________________________________________________
conv_dw_10_relu (ReLU)       (None, 14, 14, 512)       0
_________________________________________________________________
conv_pw_10 (Conv2D)          (None, 14, 14, 512)       262144
_________________________________________________________________
conv_pw_10_bn (BatchNormaliz (None, 14, 14, 512)       2048
_________________________________________________________________
conv_pw_10_relu (ReLU)       (None, 14, 14, 512)       0
_________________________________________________________________
conv_dw_11 (DepthwiseConv2D) (None, 14, 14, 512)       4608
_________________________________________________________________
conv_dw_11_bn (BatchNormaliz (None, 14, 14, 512)       2048
_________________________________________________________________
conv_dw_11_relu (ReLU)       (None, 14, 14, 512)       0
_________________________________________________________________
conv_pw_11 (Conv2D)          (None, 14, 14, 512)       262144
_________________________________________________________________
```

```
conv_pw_11_bn (BatchNormaliz (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_11_relu (ReLU)       (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pad_12 (ZeroPadding2D)  (None, 15, 15, 512)       0         
_________________________________________________________________
conv_dw_12 (DepthwiseConv2D) (None, 7, 7, 512)         4608      
_________________________________________________________________
conv_dw_12_bn (BatchNormaliz (None, 7, 7, 512)         2048      
_________________________________________________________________
conv_dw_12_relu (ReLU)       (None, 7, 7, 512)         0         
_________________________________________________________________
conv_pw_12 (Conv2D)          (None, 7, 7, 1024)        524288    
_________________________________________________________________
conv_pw_12_bn (BatchNormaliz (None, 7, 7, 1024)        4096      
_________________________________________________________________
conv_pw_12_relu (ReLU)       (None, 7, 7, 1024)        0         
_________________________________________________________________
conv_dw_13 (DepthwiseConv2D) (None, 7, 7, 1024)        9216      
_________________________________________________________________
conv_dw_13_bn (BatchNormaliz (None, 7, 7, 1024)        4096      
_________________________________________________________________
conv_dw_13_relu (ReLU)       (None, 7, 7, 1024)        0         
_________________________________________________________________
conv_pw_13 (Conv2D)          (None, 7, 7, 1024)        1048576   
_________________________________________________________________
conv_pw_13_bn (BatchNormaliz (None, 7, 7, 1024)        4096      
_________________________________________________________________
conv_pw_13_relu (ReLU)       (None, 7, 7, 1024)        0         
_________________________________________________________________
global_average_pooling2d_1 ( (None, 1024)              0         
_________________________________________________________________
dense_1 (Dense)              (None, 3)                 3075      
=================================================================
Total params: 3,231,939
Trainable params: 3,210,051
Non-trainable params: 21,888
```

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

```
model.fit(x=train_batches,
        steps_per_epoch=len(train_batches),
        validation_data=valid_batches,
        validation_steps=len(valid_batches),
        epochs=45,
        verbose=2
)
```

**Result:**

```
Epoch 1/45
300/300 - 446s - loss: 0.8082 - accuracy: 0.6523 - val_loss: 0.6368 -
val_accuracy: 0.7483
Epoch 2/45
300/300 - 490s - loss: 0.3411 - accuracy: 0.8737 - val_loss: 0.6650 -
val_accuracy: 0.7317
Epoch 3/45
300/300 - 459s - loss: 0.1986 - accuracy: 0.9327 - val_loss: 0.5288 -
val_accuracy: 0.8067
Epoch 4/45
300/300 - 402s - loss: 0.1275 - accuracy: 0.9600 - val_loss: 0.7433 -
val_accuracy: 0.7017
Epoch 5/45
300/300 - 411s - loss: 0.0929 - accuracy: 0.9750 - val_loss: 0.6221 -
val_accuracy: 0.8117
Epoch 6/45
300/300 - 405s - loss: 0.0819 - accuracy: 0.9757 - val_loss: 0.5439 -
val_accuracy: 0.8200
Epoch 7/45
300/300 - 40786s - loss: 0.0727 - accuracy: 0.9750 - val_loss: 0.7493 -
val_accuracy: 0.7583
Epoch 8/45
300/300 - 320s - loss: 0.0749 - accuracy: 0.9733 - val_loss: 1.0464 -
val_accuracy: 0.7183
Epoch 9/45
300/300 - 313s - loss: 0.0644 - accuracy: 0.9780 - val_loss: 1.0688 -
val_accuracy: 0.7350
Epoch 10/45
300/300 - 309s - loss: 0.0697 - accuracy: 0.9770 - val_loss: 0.7255 -
val_accuracy: 0.8117
Epoch 11/45
300/300 - 319s - loss: 0.0699 - accuracy: 0.9733 - val_loss: 0.5891 -
val_accuracy: 0.8283
Epoch 12/45
300/300 - 309s - loss: 0.0694 - accuracy: 0.9767 - val_loss: 0.8485 -
val_accuracy: 0.8083
```

```
Epoch 13/45
300/300 - 309s - loss: 0.0883 - accuracy: 0.9680 - val_loss: 0.8734 -
val_accuracy: 0.7883
Epoch 14/45
300/300 - 310s - loss: 0.0810 - accuracy: 0.9730 - val_loss: 0.8160 -
val_accuracy: 0.8267
Epoch 15/45
300/300 - 308s - loss: 0.0668 - accuracy: 0.9753 - val_loss: 0.7841 -
val_accuracy: 0.8200
Epoch 16/45
300/300 - 314s - loss: 0.0377 - accuracy: 0.9887 - val_loss: 0.7425 -
val_accuracy: 0.8350
Epoch 17/45
300/300 - 311s - loss: 0.0632 - accuracy: 0.9777 - val_loss: 1.3885 -
val_accuracy: 0.7733
Epoch 18/45
300/300 - 310s - loss: 0.0848 - accuracy: 0.9697 - val_loss: 0.8897 -
val_accuracy: 0.7967
Epoch 19/45
300/300 - 310s - loss: 0.0478 - accuracy: 0.9833 - val_loss: 0.9696 -
val_accuracy: 0.8117
Epoch 20/45
300/300 - 310s - loss: 0.0506 - accuracy: 0.9807 - val_loss: 0.8710 -
val_accuracy: 0.8183
Epoch 21/45
300/300 - 308s - loss: 0.0678 - accuracy: 0.9793 - val_loss: 0.7148 -
val_accuracy: 0.8500
Epoch 22/45
300/300 - 2775s - loss: 0.0554 - accuracy: 0.9827 - val_loss: 0.5984 -
val_accuracy: 0.8317
Epoch 23/45
300/300 - 312s - loss: 0.0341 - accuracy: 0.9897 - val_loss: 0.5455 -
val_accuracy: 0.8733
Epoch 24/45
300/300 - 311s - loss: 0.0572 - accuracy: 0.9820 - val_loss: 0.7362 -
val_accuracy: 0.8150
Epoch 25/45
300/300 - 310s - loss: 0.0679 - accuracy: 0.9783 - val_loss: 0.9251 -
val_accuracy: 0.8250
Epoch 26/45
300/300 - 309s - loss: 0.0372 - accuracy: 0.9890 - val_loss: 0.8609 -
val_accuracy: 0.8517
Epoch 27/45
300/300 - 310s - loss: 0.0432 - accuracy: 0.9860 - val_loss: 1.2711 -
val_accuracy: 0.7583
Epoch 28/45
```

```
300/300 - 312s - loss: 0.0293 - accuracy: 0.9893 - val_loss: 1.2968 -
val_accuracy: 0.8117
Epoch 29/45
300/300 - 311s - loss: 0.0566 - accuracy: 0.9820 - val_loss: 0.8950 -
val_accuracy: 0.8117
Epoch 30/45
300/300 - 311s - loss: 0.0416 - accuracy: 0.9867 - val_loss: 0.6869 -
val_accuracy: 0.8567
Epoch 31/45
300/300 - 310s - loss: 0.0269 - accuracy: 0.9920 - val_loss: 0.7906 -
val_accuracy: 0.8450
Epoch 32/45
300/300 - 310s - loss: 0.0326 - accuracy: 0.9897 - val_loss: 0.8588 -
val_accuracy: 0.7867
Epoch 33/45
300/300 - 311s - loss: 0.0425 - accuracy: 0.9857 - val_loss: 0.8502 -
val_accuracy: 0.8133
Epoch 34/45
300/300 - 320s - loss: 0.0315 - accuracy: 0.9900 - val_loss: 0.8716 -
val_accuracy: 0.8433
Epoch 35/45
300/300 - 311s - loss: 0.0219 - accuracy: 0.9923 - val_loss: 0.8566 -
val_accuracy: 0.8500
Epoch 36/45
300/300 - 309s - loss: 0.0323 - accuracy: 0.9927 - val_loss: 0.8248 -
val_accuracy: 0.8417
Epoch 37/45
300/300 - 309s - loss: 0.0198 - accuracy: 0.9933 - val_loss: 1.1241 -
val_accuracy: 0.8350
Epoch 38/45
300/300 - 311s - loss: 0.0132 - accuracy: 0.9967 - val_loss: 0.8218 -
val_accuracy: 0.8533
Epoch 39/45
300/300 - 311s - loss: 0.0223 - accuracy: 0.9927 - val_loss: 0.8927 -
val_accuracy: 0.8383
Epoch 40/45
300/300 - 309s - loss: 0.0636 - accuracy: 0.9823 - val_loss: 0.9921 -
val_accuracy: 0.8300
Epoch 41/45
300/300 - 309s - loss: 0.0558 - accuracy: 0.9837 - val_loss: 0.7282 -
val_accuracy: 0.8517
Epoch 42/45
300/300 - 309s - loss: 0.0240 - accuracy: 0.9910 - val_loss: 1.0447 -
val_accuracy: 0.8317
Epoch 43/45
300/300 - 311s - loss: 0.0352 - accuracy: 0.9900 - val_loss: 0.6196 -
val_accuracy: 0.8533
```

```
Epoch 44/45
300/300 - 311s - loss: 0.0318 - accuracy: 0.9883 - val_loss: 0.7156 - val_accuracy: 0.8383
Epoch 45/45
300/300 - 311s - loss: 0.0291 - accuracy: 0.9900 - val_loss: 0.7501 - val_accuracy: 0.8267
```

Out[22]:

```
<keras.callbacks.History at 0x2a8c5a26f10>
```

```
test_imgs, test_labels = next(test_batches)
plotImages(test_imgs)
print(test_labels)
```

**Results:**

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
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Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
```

```
[[1. 0. 0.]
 [1. 0. 0.]
 [1. 0. 0.]
 [1. 0. 0.]
```

```
 [1. 0. 0.]
 [1. 0. 0.]
 [1. 0. 0.]
 [1. 0. 0.]
 [1. 0. 0.]
 [1. 0. 0.]]
```

In [43]:

predictions = model.predict(x=test_batches, steps=len(test_batches), verbose=0)

from sklearn.metrics import confusion_matrix

cm = confusion_matrix(y_true=test_batches.classes, y_pred=np.argmax(predictions, axis=-1))

```
def plot_confusion_matrix(cm, classes,
            normalize=False,
            title='Confusion matrix',
            cmap=plt.cm.Blues):
    """
    This function prints and plots the confusion matrix.
    Normalization can be applied by setting `normalize=True`.
    """
    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=45)
    plt.yticks(tick_marks, classes)

    if normalize:
    cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
    print("Normalized confusion matrix")
    else:
    print('Confusion matrix, without normalization')

    print(cm)
```

```
thresh = cm.max() / 2.
for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
plt.text(j, i, cm[i, j],
horizontalalignment="center",
color="white" if cm[i, j] > thresh else "black")

plt.tight_layout()
plt.ylabel('True label')
plt.xlabel('Predicted label')
```

```
Test_batches.class_indices
```

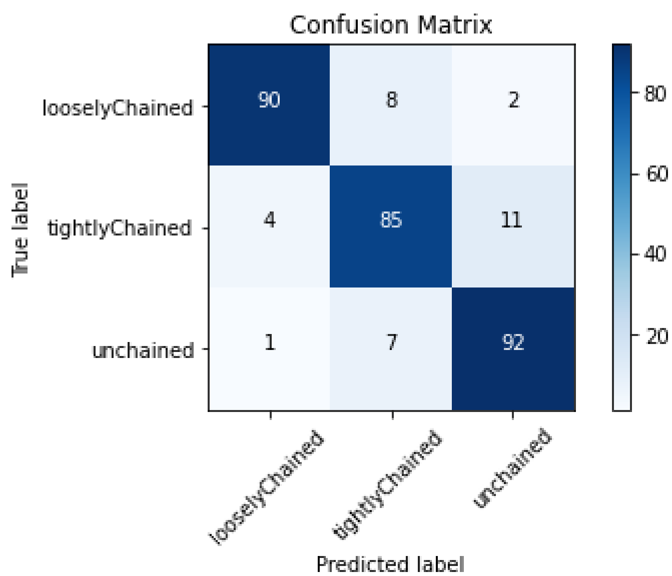
**Result:**

```
{'looselyChained': 0, 'tightlyChained': 1, 'unchained': 2}
```

```
cm_plot_labels = ['looselyChained', 'tightlyChained', 'unchained']
plot_confusion_matrix(cm=cm, classes=cm_plot_labels, title='Confusion Matrix')
```

**Result:**

```
Confusion matrix, without normalization
[[90  8  2]
 [ 4 85 11]
 [ 1  7 92]]
```



```
from sklearn.metrics import precision_recall_fscore_support
print(precision_recall_fscore_support(y_true=test_batches.classes,
y_pred=np.argmax(predictions, axis=-1), average='micro'))
```

**Result:**

```
(0.89, 0.89, 0.89, None)
```