```
%cd
shutil.rmtree('/content/hands_dataset', ignore_errors=True) #non usarloo
```

```
/root
```

```
%cd
%cd ../content
!pwd
```

```
/root
/content
/content
```

```
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, M
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.metrics import categorical_crossentropy
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from sklearn.metrics import confusion_matrix
from tensorflow.keras.models import Model
from sklearn.metrics import confusion_matrix
import itertools
import itertools
import os
import shutil
import random
import glob
import matplotlib.pyplot as plt
import warnings
from keras.callbacks import ModelCheckpoint
```

```
mobile = keras.applications.mobilenet.MobileNet()
```

```
#mobile.summary()
```

```
!pwd

!git clone https://github.com/tesiiscomingson/hands_dataset.git
```

```
/content
Cloning into 'hands_dataset'...
remote: Enumerating objects: 2696, done.
```

```
remote: Total 2696 (delta 0), reused 0 (delta 0), pack-reused 2696
Receiving objects: 100% (2696/2696), 22.06 MiB | 40.49 MiB/s, done.
Resolving deltas: 100% (863/863), done.
```

```
%cd hands_dataset
!ls
```

```
/content/hands_dataset
Dataset  Examples  LICENSE  README.md
```

```
!rm -rf Examples  LICENSE  README.md
!ls
```

```
Dataset
```

```
dir_path = os.path.dirname(os.path.realpath('FT_mobilenet.ipynb'))
print(dir_path)
```

```
/content/hands_dataset
```

```
!pwd
```

```
/content/hands_dataset
```

```
%cd /content/hands_dataset/Dataset
%mkdir train
%mkdir test
%mkdir valid
%mv 0/ 1/ 2 / 3/ 4/ 5/ 6/ 7/ 8/ 9/ train/
```

```
/content/hands_dataset/Dataset
mv: cannot move '/' to 'train': Device or resource busy
```

```
#%cd -
!pwd
%cd valid
%mkdir 0/ 1/ 2 / 3/ 4/ 5/ 6/ 7/ 8/ 9/
%cd ../test
%mkdir 0/ 1/ 2 / 3/ 4/ 5/ 6/ 7/ 8/ 9/
```

```
/content/hands_dataset/Dataset
/content/hands_dataset/Dataset/valid
mkdir: cannot create directory ‘/’: File exists
/content/hands_dataset/Dataset/test
mkdir: cannot create directory ‘/’: File exists
```

```
!pwd
```

```
     /content/hands_dataset/Dataset/test
```

```
%%bash
cd ../train
for ((i=0; i<=9; i++)); do
  a=$(find $i/ -type f | shuf -n 30)
  mv $a ../valid/$i/
  b=$(find $i/ -type f | shuf -n 5)
  mv $b ../test/$i/
done
```

```
%cd ../..
!pwd
```

```
     /content/hands_dataset
     /content/hands_dataset
```

```
train_path = 'Dataset/train'
valid_path = 'Dataset/valid'
test_path = 'Dataset/test'
```

```
train_batches = ImageDataGenerator(preprocessing_function=keras.applications.mobilenet.prepro
    train_path, target_size=(224, 224), batch_size=20)
valid_batches = ImageDataGenerator(preprocessing_function=keras.applications.mobilenet.prepro
    valid_path, target_size=(224, 224), batch_size=20)
test_batches = ImageDataGenerator(preprocessing_function=keras.applications.mobilenet.preproc
    test_path, target_size=(224, 224), batch_size=10, shuffle=False)
```

```
     Found 2172 images belonging to 10 classes.
     Found 300 images belonging to 10 classes.
     Found 50 images belonging to 10 classes.
```

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

```
     Model: "mobilenet_1.00_224"
     _________________________________________________________________
     Layer (type)                 Output Shape              Param #
     =================================================================
     input_6 (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     
```

```
x = mobile.layers[-6].output
# we take out only the last 6 layers
predictions = Dense(10, activation='softmax')(x) #si va ad aggiungere dopo l'ultimo global av
# we add the output layer
model = Model(inputs=mobile.input, outputs=predictions)
```

```
#for layer in model.layers[:-30]:
    # layer.trainable = False
```

```
model.summary()
```

```
Model: "model_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_6 (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
```

```
model.compile(Adam(lr=1e-5), loss='categorical_crossentropy', metrics=['accuracy'])
```

Interessante

mettendo tutti i layer trainabili la validation fatica a seguire il training

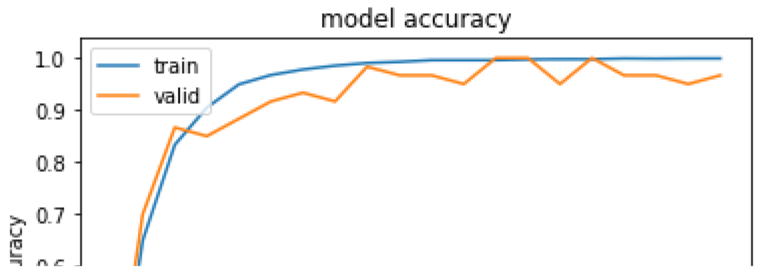
```
steps=2172/20
```

```
mc = ModelCheckpoint('best_model.h5', monitor='val_loss', mode='min', save_best_only=True)
history = model.fit_generator(train_batches, steps_per_epoch=steps,validation_data=valid_batc
```

```
Epoch 1/20
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
108/108 - 15s - loss: 2.2446 - accuracy: 0.2413 - val_loss: 2.0119 - val_accuracy: 0.28
Epoch 2/20
108/108 - 13s - loss: 1.2082 - accuracy: 0.6496 - val_loss: 1.1253 - val_accuracy: 0.70
Epoch 3/20
108/108 - 13s - loss: 0.7851 - accuracy: 0.8333 - val_loss: 0.6988 - val_accuracy: 0.86
Epoch 4/20
108/108 - 13s - loss: 0.5448 - accuracy: 0.9047 - val_loss: 0.5781 - val_accuracy: 0.85
Epoch 5/20
108/108 - 13s - loss: 0.4027 - accuracy: 0.9494 - val_loss: 0.4266 - val_accuracy: 0.88
Epoch 6/20
108/108 - 13s - loss: 0.3172 - accuracy: 0.9673 - val_loss: 0.3530 - val_accuracy: 0.91
Epoch 7/20
108/108 - 13s - loss: 0.2402 - accuracy: 0.9779 - val_loss: 0.3070 - val_accuracy: 0.93
Epoch 8/20
108/108 - 13s - loss: 0.1920 - accuracy: 0.9853 - val_loss: 0.2768 - val_accuracy: 0.91
Epoch 9/20
108/108 - 13s - loss: 0.1544 - accuracy: 0.9903 - val_loss: 0.1533 - val_accuracy: 0.98
Epoch 10/20
108/108 - 13s - loss: 0.1329 - accuracy: 0.9926 - val_loss: 0.1870 - val_accuracy: 0.96
Epoch 11/20
108/108 - 13s - loss: 0.1070 - accuracy: 0.9959 - val_loss: 0.2092 - val_accuracy: 0.96
Epoch 12/20
108/108 - 13s - loss: 0.0908 - accuracy: 0.9959 - val_loss: 0.2107 - val_accuracy: 0.95
Epoch 13/20
108/108 - 13s - loss: 0.0787 - accuracy: 0.9959 - val_loss: 0.0589 - val_accuracy: 1.00
Epoch 14/20
108/108 - 13s - loss: 0.0676 - accuracy: 0.9972 - val_loss: 0.0740 - val_accuracy: 1.00
Epoch 15/20
108/108 - 13s - loss: 0.0610 - accuracy: 0.9977 - val_loss: 0.1723 - val_accuracy: 0.95
```

```
Epoch 16/20
108/108 - 13s - loss: 0.0509 - accuracy: 0.9977 - val_loss: 0.0715 - val_accuracy: 1.000
Epoch 17/20
108/108 - 13s - loss: 0.0433 - accuracy: 0.9991 - val_loss: 0.1299 - val_accuracy: 0.96
Epoch 18/20
108/108 - 13s - loss: 0.0359 - accuracy: 0.9986 - val_loss: 0.1264 - val_accuracy: 0.96
Epoch 19/20
108/108 - 13s - loss: 0.0368 - accuracy: 0.9991 - val_loss: 0.1575 - val_accuracy: 0.95
Epoch 20/20
108/108 - 13s - loss: 0.0321 - accuracy: 0.9991 - val_loss: 0.0901 - val_accuracy: 0.96
```

```
# summarize history for accuracy
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'valid'], loc='upper left')
plt.show()
# summarize history for loss
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['train', 'valid'], loc='upper left')
plt.show()
```



```
test_labels = test_batches.classes
predictions = model.predict_generator(test_batches, steps=5, verbose=0)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1905:
  warnings.warn('`Model.predict_generator` is deprecated and '
```

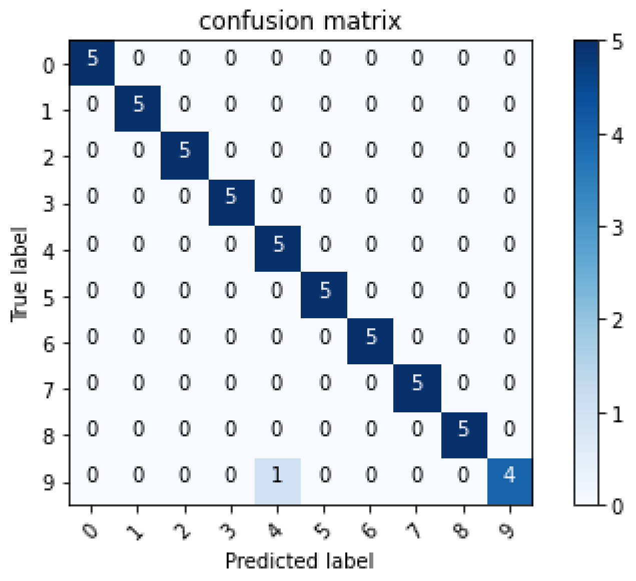
```
cm = confusion_matrix(test_labels, predictions.argmax(axis=1))
```

```
test_batches.class_indices
```

```
{'0': 0,
 '1': 1,
 '2': 2,
 '3': 3,
 '4': 4,
 '5': 5,
 '6': 6,
 '7': 7,
 '8': 8,
 '9': 9}
```

```
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')


cm_plot_labels = ['0','1','2','3','4','5','6','7','8','9']
plot_confusion_matrix(cm, cm_plot_labels, title='confusion matrix')
```

```
Confusion matrix, without normalization
[[5 0 0 0 0 0 0 0 0 0]
 [0 5 0 0 0 0 0 0 0 0]
 [0 0 5 0 0 0 0 0 0 0]
 [0 0 0 5 0 0 0 0 0 0]
 [0 0 0 0 5 0 0 0 0 0]
 [0 0 0 0 0 5 0 0 0 0]
 [0 0 0 0 0 0 5 0 0 0]
 [0 0 0 0 0 0 0 5 0 0]
 [0 0 0 0 0 0 0 0 5 0]
 [0 0 0 0 1 0 0 0 0 4]]
```



```
model.save('BDmobile_handsRGB_model.h5')


test_labels
```

```
array([0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4,
       4, 4, 4, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7, 8, 8, 8, 8,
       8, 9, 9, 9, 9, 9], dtype=int32)
```