Setup

```
import pandas as pd
import numpy as np
import os

from sklearn.utils import shuffle
from sklearn.model_selection import train_test_split,
GroupShuffleSplit
from sklearn.metrics import confusion_matrix, accuracy_score,
f1_score, precision_score, recall_score

import tensorflow as tf
from tensorflow import math
from tensorflow.keras import layers, models, metrics, optimizers,
Input, Model
from tensorflow.keras.utils import plot_model
from tensorflow.keras import backend as K

from pandas import DataFrame
import seaborn as sn

try:
    from livelossplot import PlotLossesKeras
except ImportError:
    ! pip install -q -U livelossplot
    from livelossplot import PlotLossesKeras

from tqdm import tqdm
from matplotlib import pyplot as plt
from matplotlib.figure import figure

try:
  import keras_tuner as kt
except ImportError:
  ! pip install -q -U keras-tuner
  import keras_tuner as kt
```

```
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 0.0/128.9 kB ? eta -:--:--
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 41.0/128.9 kB 876.2 kB/s eta
0:00:01 ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 128.9/128.9 kB 1.8
MB/s eta 0:00:00
```

```
def plot_conf_matrix(true_labels, predicted_labels):
    cm = confusion_matrix(true_labels, predicted_labels) # rows=true,
cols=pred
    sum_true = tf.expand_dims(tf.reduce_sum(cm, axis=1), axis=1) # sum
per row (total # true)
```

```
    norm_cm = (cm / sum_true).numpy()

    df = DataFrame(norm_cm, index=ALL_LABELS, columns=ALL_LABELS)
    # df[df == 0] = np.nan # to hide cell if value=0

    fig, ax = plt.subplots(figsize=(5,5))
    heatmap = sn.heatmap(df, cmap='Blues', cbar=False, square=True,
annot=True, fmt='.1%', ax=ax, linewidths=.2, linecolor=[0,.1,.2])
    ax.tick_params(left=False, bottom=False)
    plt.xlabel("Predicted y")
    plt.ylabel("True y")
    plt.show()
```

Dataset

```
"""
Each class is represented by a number
0    : airplane
1    : automobile
2    : bird
3    : cat
4    : deer
5    : dog
6    : frog
7    : horse
8    : ship
9    : truck
"""
NUM_LABELS = 10

(x_train, y_train), (x_test, y_test) =
tf.keras.datasets.cifar10.load_data()
y_train = y_train.reshape((50000,))
y_test = y_test.reshape((10000,))
assert x_train.shape == (50000, 32, 32, 3)
assert x_test.shape == (10000, 32, 32, 3)
assert y_train.shape == (50000,)
assert y_test.shape == (10000,)

x_train_norm = x_train / 255.0
x_test_norm = x_test / 255.0
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-
python.tar.gz
170498071/170498071 [==============================] - 31s 0us/step
```

```
ALL_LABELS = ['airplane', 'automobile', 'bird', 'cat', 'deer', 'dog',
'frog', 'horse', 'ship', 'truck']
labels_dict = {i:ALL_LABELS[i] for i in range(10)}
```

Model

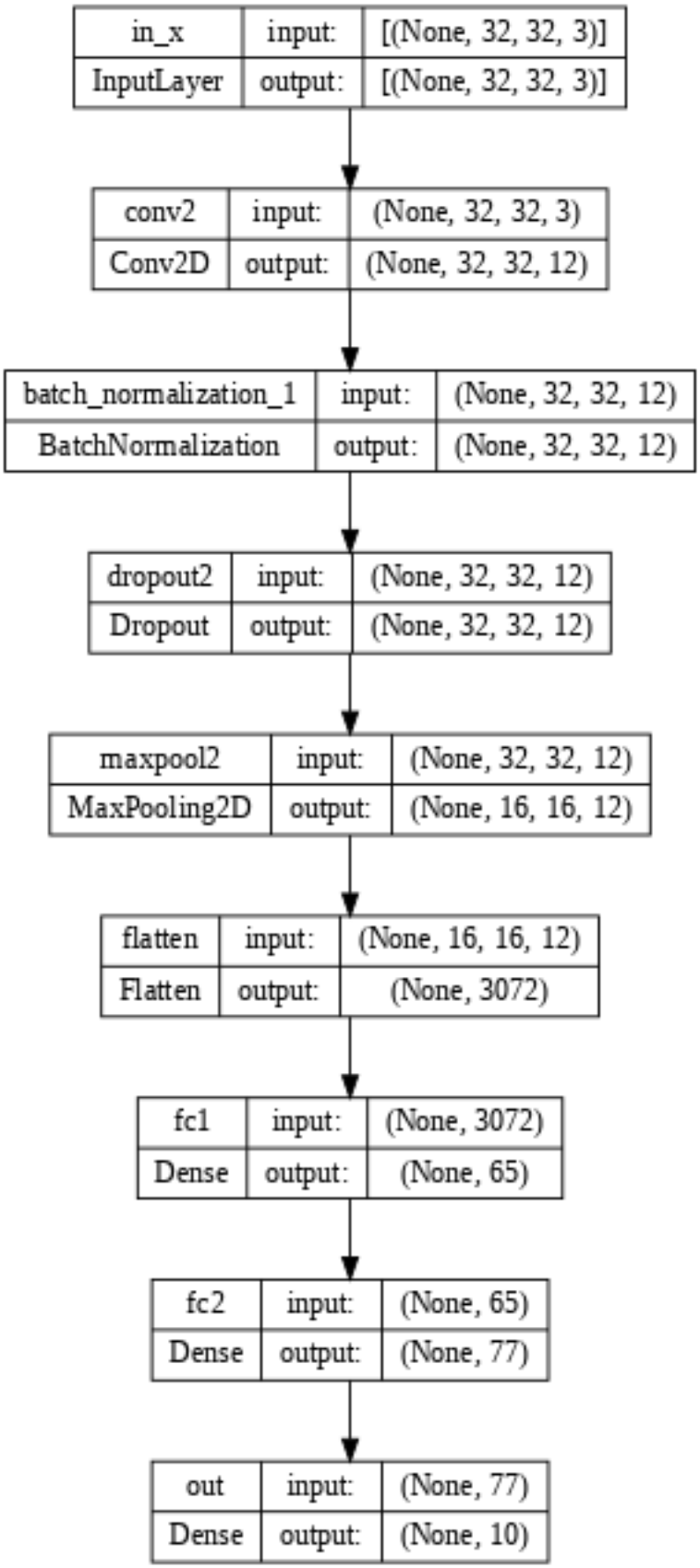
Creation

```
hp = {
    'dense1_len': 65,
    'dense2_len': 77,
    'learning_rate': 1e-4,

    'dropout_rate': 0.33 ,

    'conv1_nfilters': 67,
    'conv1_kernel_size': 3,
    'conv1_strides': 1,

    'maxpool1_width': 2,
    'maxpool1_stride': 2,

    'conv2_nfilters': 12,
    'conv2_kernel_size': 4,
    'conv2_strides': 1,

    'maxpool2_width': 2,
    'maxpool2_stride': 2,

    'conv3_nfilters': 23,
    'conv3_kernel_size': 4,
    'conv3_strides': 1,

    'maxpool3_width': 2,
    'maxpool3_stride': 2,
}

def get_model(x_shape, hp):
    x = Input(name='in_x', shape=x_shape)

    '''
    Conv blocks
    '''

    conv = layers.Conv2D(filters=hp['conv1_nfilters'],
kernel_size=hp['conv1_kernel_size'], strides=hp['conv1_strides'],
                         name='conv1', activation='relu',
kernel_regularizer='l2', padding='same')(x)
```

```
    conv = layers.BatchNormalization()(conv)
    conv = layers.Dropout(name='dropout1', rate=hp['dropout_rate'])
(conv)
    conv = layers.MaxPooling2D(name='maxpool1',
pool_size=hp['maxpool1_width'], strides=hp['maxpool1_stride'])(conv)


    conv = layers.Conv2D(filters=hp['conv2_nfilters'],
kernel_size=hp['conv2_kernel_size'], strides=hp['conv2_strides'],
                         name='conv2', activation='relu',
kernel_regularizer='l2', padding='same')(x)
    conv = layers.BatchNormalization()(conv)
    conv = layers.Dropout(name='dropout2', rate=hp['dropout_rate'])
(conv)
    conv = layers.MaxPooling2D(name='maxpool2',
pool_size=hp['maxpool2_width'], strides=hp['maxpool2_stride'])(conv)

    '''
    After adding the second block, make sure to complete the fully
connected part below. It's similar
    to what we did yesterday. I've already flattened it for you.

    Now, train your model. See if it does well. Let me know once
you've done this.

    After training with two blocks and talking to me, try adding a
third "block" to improve performance.
    '''


    '''
    Fully connected
    '''
    flatten = layers.Flatten(name='flatten')(conv)
    fc = layers.Dense(name='fc1', units=hp['dense1_len'],
activation='relu', kernel_regularizer='l2')(flatten)
    fc = layers.Dense(name='fc2', units=hp['dense2_len'],
activation='relu', kernel_regularizer='l2')(fc)

    out = layers.Dense(name='out', activation='softmax',
units=NUM_LABELS)(fc)



    # compiling the model...
    model = Model(name="model", inputs=x, outputs=out)
    model.compile(

optimizer=optimizers.Adam(learning_rate=hp['learning_rate'],
clipnorm=1.0), # clipnorm=1.0 does gradient clipping to stop gradient
```

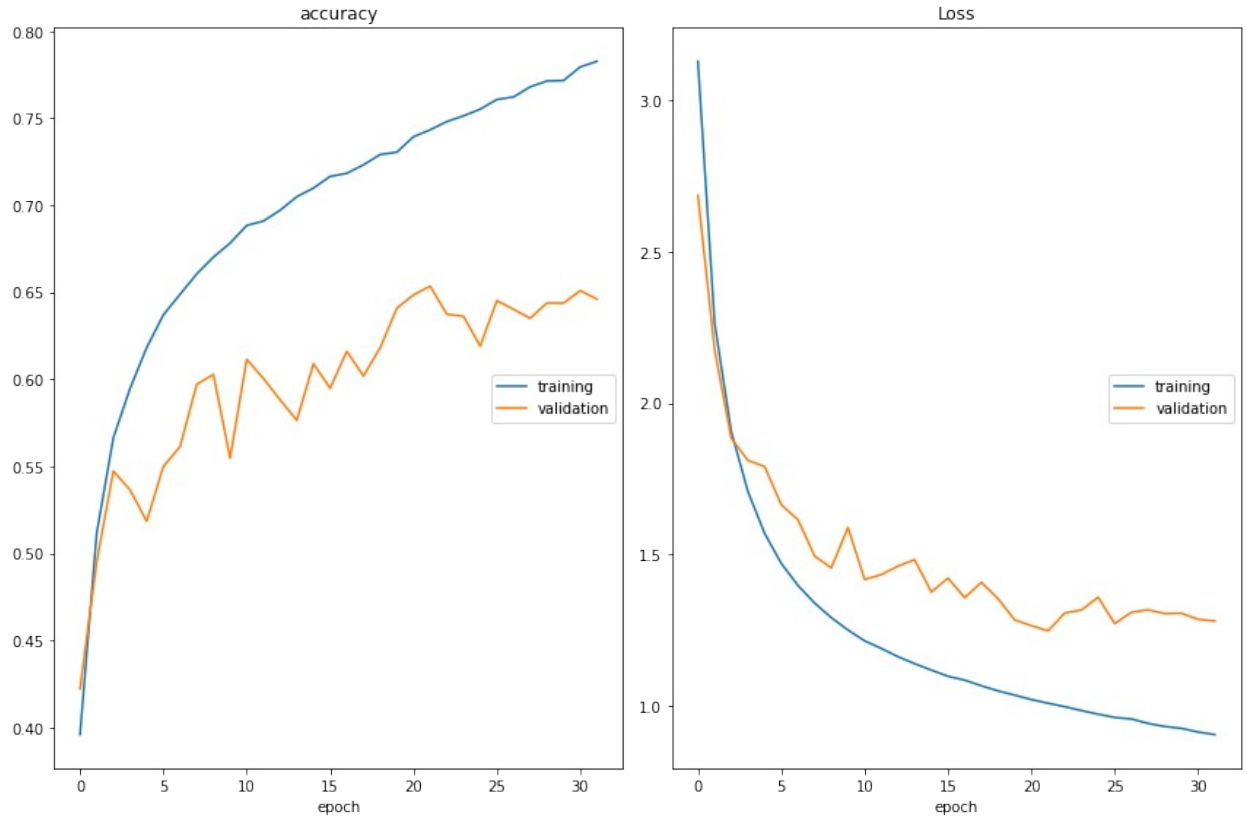
```
explosion
                loss=tf.keras.losses.CategoricalCrossentropy(),
                metrics=['accuracy'])
    return model

model = get_model(x_train_norm[0].shape, hp)
model.summary()
plot_model(model, show_shapes=True, dpi=64)
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 in_x (InputLayer)           [(None, 32, 32, 3)]       0

 conv2 (Conv2D)              (None, 32, 32, 12)        588

 batch_normalization_1 (Batc  (None, 32, 32, 12)       48
 hNormalization)

 dropout2 (Dropout)          (None, 32, 32, 12)        0

 maxpool2 (MaxPooling2D)     (None, 16, 16, 12)        0

 flatten (Flatten)           (None, 3072)              0

 fc1 (Dense)                 (None, 65)                199745

 fc2 (Dense)                 (None, 77)                5082

 out (Dense)                 (None, 10)                780

=================================================================
Total params: 206,243
Trainable params: 206,219
Non-trainable params: 24
_________________________________________________________________
```


in_x | input: | [(None, 32, 32, 3)]
InputLayer | output: | [(None, 32, 32, 3)]
conv2 | input: | (None, 32, 32, 3)
Conv2D | output: | (None, 32, 32, 12)
batch_normalization_1 | input: | (None, 32, 32, 12)
BatchNormalization | output: | (None, 32, 32, 12)
dropout2 | input: | (None, 32, 32, 12)
Dropout | output: | (None, 32, 32, 12)
maxpool2 | input: | (None, 32, 32, 12)
MaxPooling2D | output: | (None, 16, 16, 12)
flatten | input: | (None, 16, 16, 12)
Flatten | output: | (None, 3072)
fc1 | input: | (None, 3072)
Dense | output: | (None, 65)
fc2 | input: | (None, 65)
Dense | output: | (None, 77)
out | input: | (None, 77)
Dense | output: | (None, 10)

Training

```
tf.random.set_seed(42)
model = get_model(x_train_norm[0].shape, hp)
history = model.fit(x_train_norm, tf.one_hot(y_train,
depth=NUM_LABELS),
                    epochs=40,

callbacks=[tf.keras.callbacks.EarlyStopping(monitor='val_loss',
patience=10),
                               PlotLossesKeras()],
                    validation_data=(x_test_norm,
tf.one_hot(y_test, depth=NUM_LABELS))
                    )
```




```
accuracy
      training                 (min:    0.396, max:    0.783, cur:
0.783)
      validation               (min:    0.422, max:    0.654, cur:
0.646)
Loss
      training                 (min:    0.905, max:    3.128, cur:
0.905)
      validation               (min:    1.248, max:    2.685, cur:
```

```
1.280)
 1563/1563 [==============================] - 8s 5ms/step - loss:
0.9051 - accuracy: 0.7826 - val_loss: 1.2803 - val_accuracy: 0.6461
```

Results

Training Performance

```
y_train_probs = model.predict(x_train_norm)
model_train_pred = [np.argmax(y) for y in y_train_probs]
```

```
---------------------------------------------------------------------------
-----
NameError                                 Traceback (most recent call
last)
<ipython-input-2-c58d7949fb16> in <cell line: 1>()
----> 1 y_train_probs = model.predict(x_train_norm)
      2 model_train_pred = [np.argmax(y) for y in y_train_probs]

NameError: name 'model' is not defined
```

```
print("Training Performance")
print("Accuracy", accuracy_score(y_train, model_train_pred))
print("F1 Score (macro)", f1_score(y_train, model_train_pred,
average='macro'))
plot_conf_matrix(y_train, model_train_pred)
```

Test Performance

```
y_test_probs = model.predict(x_test_norm)
model_test_pred = [np.argmax(y) for y in y_test_probs]

print("Test Performance")
print("Accuracy", accuracy_score(y_test, model_test_pred))
print("F1 Score (macro)", f1_score(y_test, model_test_pred,
average='macro'))
plot_conf_matrix(y_test, model_test_pred)

for i in range(10):
    print(f'TEST IMAGE {i}')
    print('Predicted:', labels_dict[model_test_pred[i]])
    print('Actual:', labels_dict[y_test[i]])
    print('Image:')
    plt.imshow(x_test[i], cmap='gray')
    plt.show()
```