cnn_v2

October 12, 2022

```
[ ]: %env LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$CONDA_PREFIX/lib/
```

```
env: LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$CONDA_PREFIX/lib/
```

```
[ ]: import os
     print(os.environ["LD_LIBRARY_PATH"])
```

```
$LD_LIBRARY_PATH:$CONDA_PREFIX/lib/
```

```
[ ]: import tensorflow as tf
     import numpy as np
     import pandas as pd
     import os
     import keras

     from keras import Sequential, models, Input
     from keras.layers import Dense, Flatten, Conv2D, MaxPooling2D, Dropout,␣
      ↪LeakyReLU
     from keras.optimizers import SGD, Adam
```

```
[ ]: from tensorflow.python.client import device_lib

     #print(device_lib.list_local_devices())
     print('Default GPU Device: {}'.format(tf.test.gpu_device_name()))
```

0.1 Read the csv dataset to get the values for stage and discharge of the images

```
[ ]: df = pd.read_csv("../dataset/2012_2019_PlatteRiverWeir_features_merged_all.csv")
     df.head()
```

```
[ ]:    Unnamed: 0           SensorTime          CaptureTime  \
     0           0  2012-06-09 13:15:00  2012-06-09T13:09:07
     1           1  2012-06-09 13:15:00  2012-06-09T13:10:29
     2           2  2012-06-09 13:45:00  2012-06-09T13:44:01
     3           3  2012-06-09 14:45:00  2012-06-09T14:44:30
     4           4  2012-06-09 15:45:00  2012-06-09T15:44:59
```

```
                                 Filename Agency  SiteNumber TimeZone  Stage  \
0  StateLineWeir_20120609_Farrell_001.jpg   USGS     6674500      MDT   2.99
1  StateLineWeir_20120609_Farrell_002.jpg   USGS     6674500      MDT   2.99
2  StateLineWeir_20120609_Farrell_003.jpg   USGS     6674500      MDT   2.96
3  StateLineWeir_20120609_Farrell_004.jpg   USGS     6674500      MDT   2.94
4  StateLineWeir_20120609_Farrell_005.jpg   USGS     6674500      MDT   2.94

   Discharge        CalcTimestamp  …  WeirPt2X  WeirPt2Y  WwRawLineMin  \
0      916.0  2020-03-11T16:58:28  …        -1        -1           0.0
1      916.0  2020-03-11T16:58:33  …        -1        -1           0.0
2      873.0  2020-03-11T16:58:40  …        -1        -1           0.0
3      846.0  2020-03-11T16:58:47  …        -1        -1           0.0
4      846.0  2020-03-11T16:58:55  …        -1        -1           0.0

   WwRawLineMax  WwRawLineMean  WwRawLineSigma  WwCurveLineMin  \
0           0.0            0.0             0.0             0.0
1           0.0            0.0             0.0             0.0
2           0.0            0.0             0.0             0.0
3           0.0            0.0             0.0             0.0
4           0.0            0.0             0.0             0.0

   WwCurveLineMax  WwCurveLineMean  WwCurveLineSigma
0             0.0              0.0               0.0
1             0.0              0.0               0.0
2             0.0              0.0               0.0
3             0.0              0.0               0.0
4             0.0              0.0               0.0

[5 rows x 60 columns]
```

[ ]:

```
df = df[["Filename", "Stage", "Discharge"]]
```

0.1.1 Scale the data

[ ]:

```
from sklearn.preprocessing import StandardScaler

scaler = StandardScaler()
```

[ ]:

```
df[["Stage", "Discharge"]] = scaler.fit_transform(df[["Stage", "Discharge"]])
df
```

[ ]:

```
                                     Filename     Stage  Discharge
0      StateLineWeir_20120609_Farrell_001.jpg  0.138117  -0.046094
1      StateLineWeir_20120609_Farrell_002.jpg  0.138117  -0.046094
2      StateLineWeir_20120609_Farrell_003.jpg  0.100875  -0.082160
3      StateLineWeir_20120609_Farrell_004.jpg  0.076046  -0.104807
4      StateLineWeir_20120609_Farrell_005.jpg  0.076046  -0.104807
```

```
…                                        …         …         …
42054  StateLineWeir_20191011_Farrell_409.jpg -0.420526  -0.450369
42055  StateLineWeir_20191011_Farrell_410.jpg -0.420526  -0.450369
42056  StateLineWeir_20191011_Farrell_411.jpg -0.420526  -0.450369
42057  StateLineWeir_20191011_Farrell_412.jpg -0.420526  -0.450369
42058  StateLineWeir_20191011_Farrell_413.jpg -0.420526  -0.450369

[42059 rows x 3 columns]
```

0.2 Create the dataset pipeline

[ ]:

```
IMG_SIZE = 512
```

[ ]:

```
from glob import glob

def make_dataset(path, batch_size, df, seed=None):
  np.random.seed(seed)

  def parse_image(filename):
    image = tf.io.read_file(filename)
    image = tf.image.decode_jpeg(image, channels=3)
    #image = tf.image.resize(image, [IMG_SIZE, IMG_SIZE])
    image = tf.cast(image, tf.float32)
    image /= 255
    return image

  def configure_for_performance(ds):
    ds = ds.shuffle(buffer_size=100)
    ds = ds.batch(batch_size)
    ds = ds.repeat()
    ds = ds.prefetch(buffer_size=tf.data.experimental.AUTOTUNE)
    return ds

  filenames = glob(path + '/*')
  # make train, val and test splits of the dataset
  split1 = int(0.7 * len(filenames))
  split2 = int(0.8 * len(filenames))

  np.random.shuffle(filenames)
  train_files = filenames[:split1] # up to split 1 (ex 70%)
  val_files = filenames[split1:split2] # from ex. 70% to 80%
  test_files = filenames[split2:] # from ex. 80% until the end

  # create stage values
  stage_train_values = [df[df.Filename == file.split('/')[-1]].Stage.values for␣
↪file in train_files]
```

```
stage_val_values = [df[df.Filename == file.split('/')[-1]].Stage.values for␣
↪file in val_files]
stage_test_values = [df[df.Filename == file.split('/')[-1]].Stage.values for␣
↪file in test_files]

# create discharge values
discharge_train_values = [df[df.Filename == file.split(
    '/')[-1]].Discharge.values for file in train_files]
discharge_val_values = [df[df.Filename == file.split(
    '/')[-1]].Discharge.values for file in val_files]
discharge_test_values = [df[df.Filename == file.split(
    '/')[-1]].Discharge.values for file in test_files]

# join stage and discharge values
stage_discharge_train_values = [[np.squeeze(s), np.squeeze(d)] for s, d in␣
↪zip(stage_train_values, discharge_train_values)]
stage_discharge_val_values = [[np.squeeze(s), np.squeeze(d)] for s, d in␣
↪zip(stage_val_values, discharge_val_values)]
stage_discharge_test_values = [[np.squeeze(s), np.squeeze(
    d)] for s, d in zip(stage_test_values, discharge_test_values)]

# create images dataset (train, val, test)
filenames_train_ds = tf.data.Dataset.from_tensor_slices(train_files)
filenames_val_ds = tf.data.Dataset.from_tensor_slices(val_files)
filenames_test_ds = tf.data.Dataset.from_tensor_slices(test_files)

images_train_ds = filenames_train_ds.map(parse_image, num_parallel_calls=5)
images_val_ds = filenames_val_ds.map(parse_image, num_parallel_calls=5)
images_test_ds = filenames_test_ds.map(parse_image, num_parallel_calls=5)

# create stage and discharge dataset (train, val, test)
stage_discharge_train_ds = tf.data.Dataset.
↪from_tensor_slices(stage_discharge_train_values)
stage_discharge_val_ds = tf.data.Dataset.
↪from_tensor_slices(stage_discharge_val_values)
stage_discharge_test_ds = tf.data.Dataset.from_tensor_slices(
    stage_discharge_test_values)

# create tensorflow dataset of images and values (train, val, test)
train_ds = tf.data.Dataset.zip((images_train_ds, stage_discharge_train_ds))
train_ds = configure_for_performance(train_ds)
val_ds = tf.data.Dataset.zip((images_val_ds, stage_discharge_val_ds))
val_ds = configure_for_performance(val_ds)
test_ds = tf.data.Dataset.zip((images_test_ds, stage_discharge_test_ds))
test_ds = configure_for_performance(test_ds)
```

```
  return train_ds, len(train_files), val_ds, len(val_files), test_ds,␣
↪len(test_files)
```

[ ]:

```
path = "../dataset/images_tmp"

train_ds, train_size, val_ds, val_size, test_ds, test_size = make_dataset(path,␣
↪32, df, 0)
```

[ ]:

```
input_shape = 0
output_shape = 0

for image, stage_discharge in train_ds.take(1):
    print(image.numpy().shape)
    print(stage_discharge.numpy().shape)

    input_shape = image.numpy().shape[1:]
    output_shape = stage_discharge.numpy().shape[1:]
```

```
(32, 512, 512, 3)
(32, 2)
```

[ ]:

```
print(input_shape)
print(output_shape)
```

```
(512, 512, 3)
(2,)
```

0.3 Create model

[ ]:

```
def create_model(input_shape, output_shape):
    model = Sequential()

    model.add(Input(shape=input_shape))

    model.add(Conv2D(64, kernel_size=(4, 4), strides=(2, 2), padding='same',␣
↪activation=LeakyReLU()))
    model.add(MaxPooling2D(pool_size=(4, 4)))
    model.add(Conv2D(64, kernel_size=(4, 4), activation=LeakyReLU(),␣
↪padding='same'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Conv2D(32, kernel_size=(3, 3), activation='relu', padding='same'))
    model.add(MaxPooling2D(pool_size=(3, 3)))
    model.add(Conv2D(32, kernel_size=(3, 3), activation='relu'))
    model.add(MaxPooling2D(pool_size=(2, 2)))


    model.add(Flatten())
    model.add(Dense(64, activation='relu'))
    model.add(Dropout(0.3))
    model.add(Dense(32, activation='sigmoid'))
    #model.add(Dropout(0.3))
    model.add(Dense(32, activation='sigmoid'))
    model.add(Dense(output_shape, activation='linear')) # linear regression␣
↪output layer

    return model
```

```
[ ]: model = create_model(input_shape, output_shape[0])
```

```
[ ]: model.summary()
```

```
Model: "sequential_2"

_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_8 (Conv2D)           (None, 256, 256, 64)      3136

 max_pooling2d_8 (MaxPooling  (None, 64, 64, 64)       0
 2D)

 conv2d_9 (Conv2D)           (None, 64, 64, 64)        65600

 max_pooling2d_9 (MaxPooling  (None, 32, 32, 64)       0
 2D)

 conv2d_10 (Conv2D)          (None, 32, 32, 32)        18464

 max_pooling2d_10 (MaxPoolin  (None, 10, 10, 32)       0
 g2D)

 conv2d_11 (Conv2D)          (None, 8, 8, 32)          9248

 max_pooling2d_11 (MaxPoolin  (None, 4, 4, 32)         0
 g2D)

 flatten_2 (Flatten)         (None, 512)               0

 dense_8 (Dense)             (None, 64)                32832

 dropout_2 (Dropout)         (None, 64)                0

 dense_9 (Dense)             (None, 32)                2080

 dense_10 (Dense)            (None, 32)                1056
 dense_11 (Dense)            (None, 2)                 66

=================================================================
Total params: 132,482
Trainable params: 132,482
Non-trainable params: 0
_________________________________________________________________
```

[ ]:
```
def compile_model(loss_func, optimizer, metrics=["accuracy"]):
    model.compile(loss=loss_func, optimizer=optimizer, metrics=metrics)
```

[ ]:
```
sgd = SGD(learning_rate=0.01, decay=1e-4, momentum=0.9, nesterov=True)
adam = Adam(learning_rate=1e-3, decay=1e-3 / 200)

compile_model('mse', adam,  [
              'mse', tf.keras.metrics.RootMeanSquaredError(name='rmse'), 'mae',␣
 ↪'mape'])
```

[ ]:
```
def fit_model(training_values, validation_values=None, batch_size=32,␣
 ↪epochs=10, steps=32, val_steps=32, callbacks=[]):
    return model.fit(training_values, validation_data=validation_values,␣
 ↪batch_size=batch_size, epochs=epochs, steps_per_epoch=steps,␣
 ↪validation_steps=val_steps, callbacks=callbacks)
```

[ ]:
```
import datetime

log_dir = "logs/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir,␣
 ↪histogram_freq=1)

checkpoint_callback = tf.keras.callbacks.
 ↪ModelCheckpoint(filepath="model_weights/cnn_best_weights.hdf5",
                               monitor='val_mape',
                               verbose=1,
                               save_best_only=True)
```

[ ]:
```
# batch_size = 0 because we already have batch size in tf dataset
history = fit_model(train_ds, val_ds, batch_size=0, epochs=20, steps=np.
 ↪ceil(train_size / 32), val_steps=np.ceil(val_size / 32),␣
 ↪callbacks=[tensorboard_callback, checkpoint_callback])
```

0.4 Evaluate model

```
[ ]: def evaluate_model(test_values, steps):
       score = model.evaluate(test_values, steps=steps)
       return score
```

```
[ ]: test_loss, test_mse, test_rmse, test_mae, test_mape = evaluate_model(test_ds,␣
      ↪steps=np.ceil(test_size / 32))
```

```
57/57 [==============================] - 3s 59ms/step - loss: 0.0161 - mse:
0.0161 - rmse: 0.1267 - mae: 0.0881 - mape: 46.2712
```

```
[ ]: predictions = model.predict(test_ds, steps=np.ceil(test_size / 32))
```

```
57/57 [==============================] - 3s 56ms/step
```

```
[ ]: for image, stage_discharge in train_ds.take(1):
             diff = predictions[:2].flatten() - stage_discharge[:2].numpy().flatten()
             percentDiff = (diff / stage_discharge[:2].numpy().flatten()) * 100
             absPercentDiff = np.abs(percentDiff)
             # compute the mean and standard deviation of the absolute percentage
             # difference
             mean = np.mean(absPercentDiff)
             std = np.std(absPercentDiff)
             # finally, show some statistics on our model
             print(mean)
             print(std)
             print(f"pred stage: {scaler.inverse_transform(predictions[:2])[0]},␣
      ↪actual stage: {scaler.inverse_transform(stage_discharge[:2].numpy())[0]}")
             print(f"pred discharge: {scaler.inverse_transform(predictions[:2])[0]},␣
      ↪actual discharge: {scaler.inverse_transform(stage_discharge[:2].
      ↪numpy())[0]}")
```

```
106.0863843262142
62.035046289328605
pred stage: [  2.352   269.60703], actual stage: [   3.71 2010.  ]
pred discharge: [  2.352   269.60703], actual discharge: [   3.71 2010.  ]
```

```
[ ]:
```

0.5 Visualize layers

```
[ ]: layer_outputs = [layer.output for layer in model.layers[:12]]
     # Extracts the outputs of the top 12 layers
     activation_model = models.Model(inputs=model.input, outputs=layer_outputs) #␣
      ↪Creates a model that will return these outputs, given the model input
```

```
[ ]: activations = activation_model.predict(test_ds, steps=np.ceil(test_size / 32))
```

```
2/2 [==============================] - 0s 42ms/step
```

[ ]:

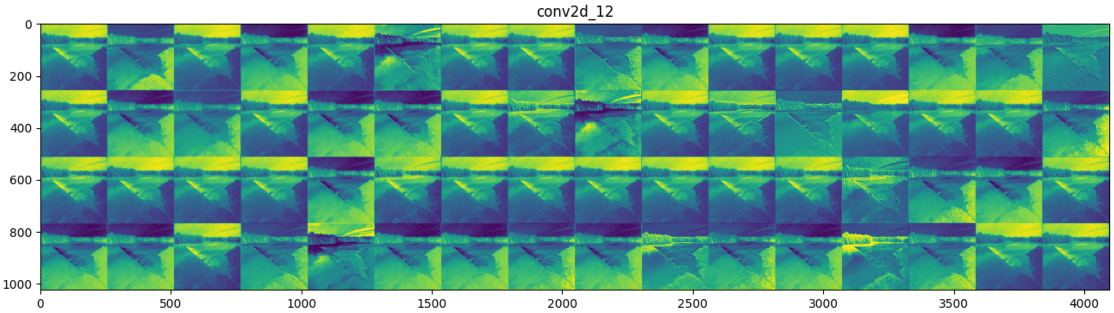
```
import matplotlib.pyplot as plt

layer_names = []
for layer in model.layers[:12]:
    layer_names.append(layer.name) # Names of the layers, so you can have them␣
 ↪as part of your plot

images_per_row = 16

for layer_name, layer_activation in zip(layer_names, activations): # Displays␣
 ↪the feature maps
    n_features = layer_activation.shape[-1] # Number of features in the feature␣
 ↪map
    size = layer_activation.shape[1] #The feature map has shape (1, size, size,␣
 ↪n_features).
    n_cols = n_features // images_per_row # Tiles the activation channels in␣
 ↪this matrix
    display_grid = np.zeros((size * n_cols, images_per_row * size))

    print(layer_name)
    if ("Dense" in layer_name): break

    for col in range(n_cols): # Tiles each filter into a big horizontal grid
        for row in range(images_per_row):
            channel_image = layer_activation[0,
                                             :, :,
                                             col * images_per_row + row]
            channel_image -= channel_image.mean() # Post-processes the feature␣
 ↪to make it visually palatable
            channel_image /= channel_image.std()
            channel_image *= 64
            channel_image += 128
            channel_image = np.clip(channel_image, 0, 255).astype('uint8')
            display_grid[col * size : (col + 1) * size, # Displays the grid
                         row * size : (row + 1) * size] = channel_image
    scale = 1. / size
    plt.figure(figsize=(scale * display_grid.shape[1],
                        scale * display_grid.shape[0]))
    plt.title(layer_name)
    plt.grid(False)
    plt.imshow(display_grid, aspect='auto', cmap='viridis')
```

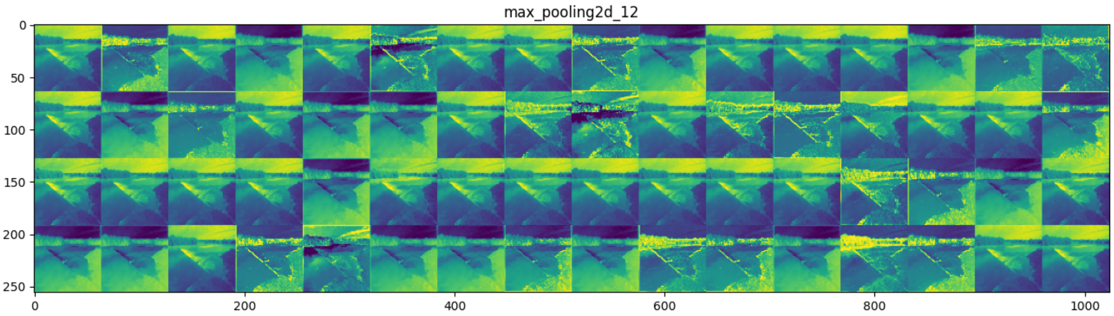
```
conv2d_12
max_pooling2d_12
conv2d_13
```

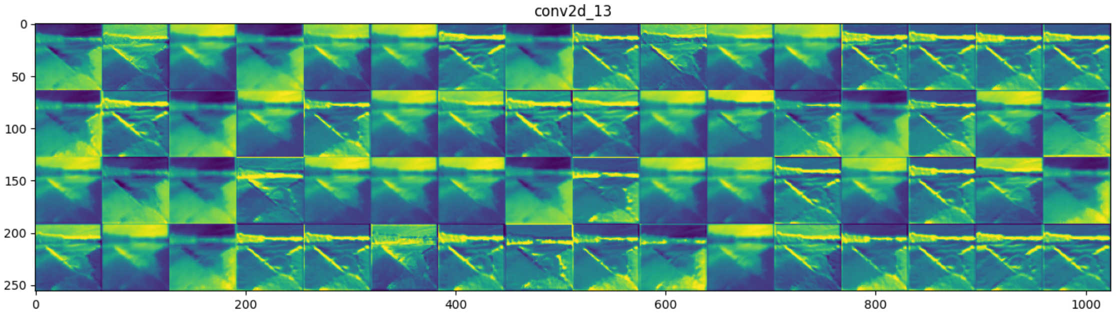
```
max_pooling2d_13
conv2d_14
max_pooling2d_14
conv2d_15
max_pooling2d_15
flatten_3
```

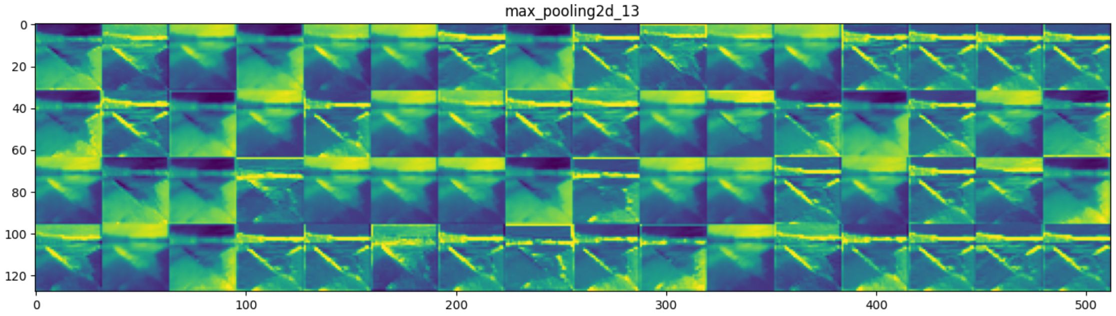
```
/tmp/ipykernel_19196/1622603125.py:24: RuntimeWarning: invalid value encountered
in divide
  channel_image /= channel_image.std()
```

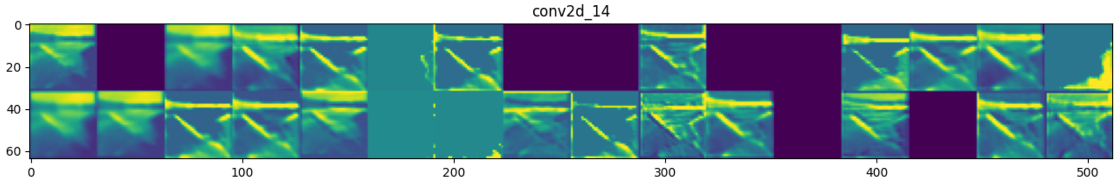
```
---------------------------------------------------------------------------
IndexError                                Traceback (most recent call last)
Cell In [71], line 20
     18 for col in range(n_cols): # Tiles each filter into a big horizontal gri
     19     for row in range(images_per_row):
---> 20         channel_image = layer_activation[0,
     21                                          :, :,
     22                                          col * images_per_row + row]
     23         channel_image -= channel_image.mean() # Post-processes the␣
 ↪feature to make it visually palatable
     24         channel_image /= channel_image.std()

IndexError: too many indices for array: array is 2-dimensional, but 4 were␣
 ↪indexed
```

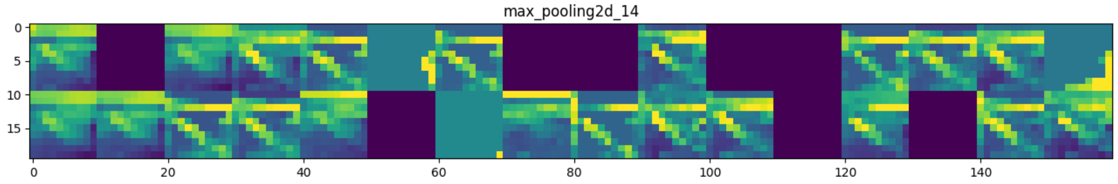


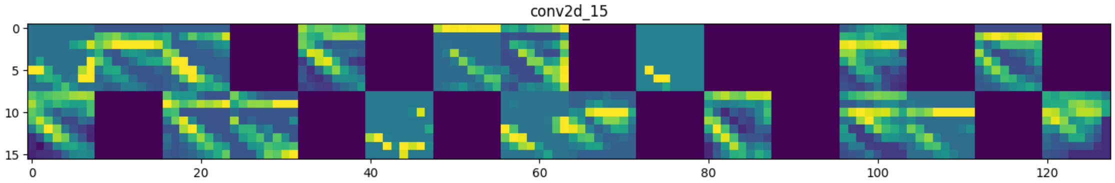


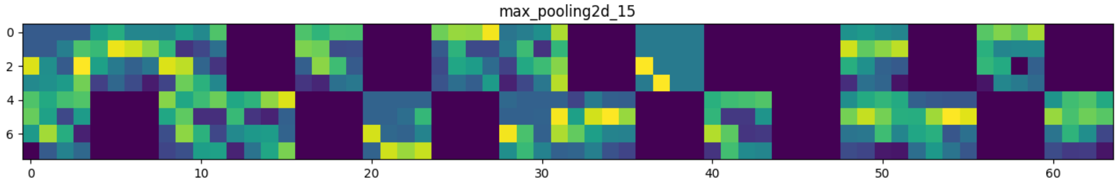

conv2d_13
0
50
100
150
200
250
0
200
400
600
800
1000


max_pooling2d_13
0
20
40
60
80
100
120
0
100
200
300
400
500


conv2d_14
0
20
40
60
0
100
200
300
400
500


max_pooling2d_14
0
5
10
15
0
20
40
60
80
100
120
140


conv2d_15
0
5
10
15
0
20
40
60
80
100
120


max_pooling2d_15
0
2
4
6
0
10
20
30
40
50
60