

```
In [1]: # CSC 732 Final Part 2 Problem 1 Relu Softmax Adagrad Test Case
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from IPython.core.display import display, HTML
display(HTML("<style>.container { width:98% !important; }</style>"))
```

## Dataset Information

Beginner set of 16,000 custom images for categorizing polyhedral dice. Polyhedral dice vary in color, and images are taken at different angles over different background types: blank, colored, and wood. All images were created, edited, and sorted by Mario Lurig. Fixed camera positions (minimum 2 angles) used to capture video on a rotating platform with two white lights Minimum 5 different dice used on 6 different backgrounds (white and various colors) Video was then exported as images and then batch cropped to 480x480 Handheld camera moved over 5+ dice on various wood surfaces (minimum 2) using natural lighting Video edited and exported to images then batch cropped to 480x480 Images that were partially out of crop were manually removed

- **Number of Instances:** 16,000
- **Number of Classes:** 6
- **Image Dimensions:** 480x480
- **Number of Channels:** 3

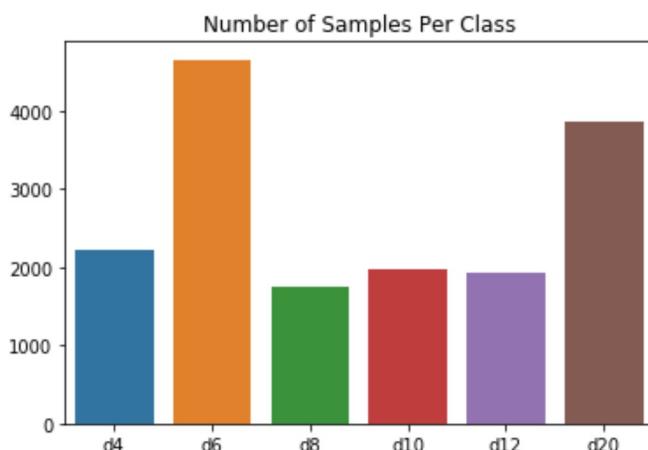
```
In [2]: import keras
from keras.datasets import mnist
from keras.models import Sequential
from keras.layers.normalization import BatchNormalization
from keras.layers.convolutional import Conv2D, MaxPooling2D
from keras.layers.core import Flatten, Dropout, Dense, Activation
from keras.preprocessing.image import ImageDataGenerator
from keras.utils import to_categorical
from keras import backend as K
from skimage import transform
from sklearn.utils import shuffle
import matplotlib.image as mpimg
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import tqdm
import pickle
import os
import glob
```

Using TensorFlow backend.

```
In [3]: # set some hyper parameters for training  
batch_size = 32  
num_classes = 6  
num_epochs = 50
```

## View Dataset Frequencies

```
In [4]: # find files in each folder of dataset  
d4_list = os.listdir('Datasets/Dice/dataset/d4')  
d6_list = os.listdir('Datasets/Dice/dataset/d6')  
d8_list = os.listdir('Datasets/Dice/dataset/d8')  
d10_list = os.listdir('Datasets/Dice/dataset/d10')  
d12_list = os.listdir('Datasets/Dice/dataset/d12')  
d20_list = os.listdir('Datasets/Dice/dataset/d20')  
d4_size = len(d4_list)  
d6_size = len(d6_list)  
d8_size = len(d8_list)  
d10_size = len(d10_list)  
d12_size = len(d12_list)  
d20_size = len(d20_list)  
  
In [5]: sns.barplot([0,1,2,3,4,5], [d4_size, d6_size, d8_size, d10_size, d12_size, d20_size])  
plt.xticks(range(6), ['d4', 'd6', 'd8', 'd10', 'd12', 'd20'])  
plt.title("Number of Samples Per Class")  
plt.show()
```

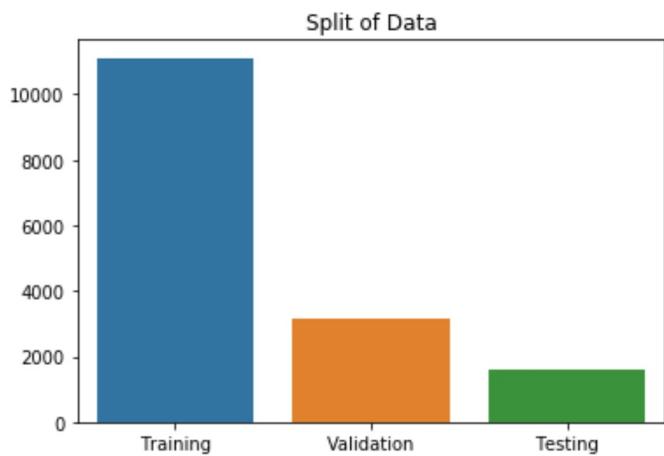


```
In [6]: train_size = 0
validation_size = 0
test_size = 0
# find size of training set
d4_list = os.listdir('Datasets/train/d4')
d6_list = os.listdir('Datasets/train/d6')
d8_list = os.listdir('Datasets/train/d8')
d10_list = os.listdir('Datasets/train/d10')
d12_list = os.listdir('Datasets/train/d12')
d20_list = os.listdir('Datasets/train/d20')
d4_size = len(d4_list)
d6_size = len(d6_list)
d8_size = len(d8_list)
d10_size = len(d10_list)
d12_size = len(d12_list)
d20_size = len(d20_list)
train_size = d4_size + d6_size + d8_size + d10_size + d12_size + d20_size

# find size of validation set
d4_list = os.listdir('Datasets/val/d4')
d6_list = os.listdir('Datasets/val/d6')
d8_list = os.listdir('Datasets/val/d8')
d10_list = os.listdir('Datasets/val/d10')
d12_list = os.listdir('Datasets/val/d12')
d20_list = os.listdir('Datasets/val/d20')
d4_size = len(d4_list)
d6_size = len(d6_list)
d8_size = len(d8_list)
d10_size = len(d10_list)
d12_size = len(d12_list)
d20_size = len(d20_list)
validation_size = d4_size + d6_size + d8_size + d10_size + d12_size + d20_size

# find size of test set
d4_list = os.listdir('Datasets/test/d4')
d6_list = os.listdir('Datasets/test/d6')
d8_list = os.listdir('Datasets/test/d8')
d10_list = os.listdir('Datasets/test/d10')
d12_list = os.listdir('Datasets/test/d12')
d20_list = os.listdir('Datasets/test/d20')
d4_size = len(d4_list)
d6_size = len(d6_list)
d8_size = len(d8_list)
d10_size = len(d10_list)
d12_size = len(d12_list)
```

```
In [7]: sns.barplot([0,1,2], [train_size, validation_size, test_size])
plt.xticks(range(3), ['Training', 'Validation', 'Testing'])
plt.title("Split of Data")
plt.show()
```

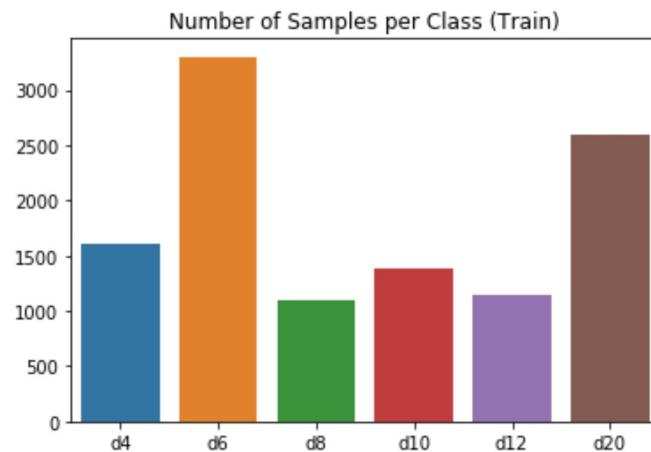


```
In [8]: train_size = 0
validation_size = 0
test_size = 0
# find size of training set
d4_list = os.listdir('Datasets/train/d4')
d6_list = os.listdir('Datasets/train/d6')
d8_list = os.listdir('Datasets/train/d8')
d10_list = os.listdir('Datasets/train/d10')
d12_list = os.listdir('Datasets/train/d12')
d20_list = os.listdir('Datasets/train/d20')
d4_size = len(d4_list)
d6_size = len(d6_list)
d8_size = len(d8_list)
d10_size = len(d10_list)
d12_size = len(d12_list)
d20_size = len(d20_list)
print("Samples for Training Set")
print("D4 : ", d4_size)
print("D6 : ", d6_size)
print("D8 : ", d8_size)
print("D10 : ", d10_size)
print("D12 : ", d12_size)
print("D20 : ", d20_size)
train_size = d4_size + d6_size + d8_size + d10_size + d12_size + d20_size
sns.barplot([0,1,2,3,4,5], [d4_size, d6_size, d8_size, d10_size, d12_size, d20_size])
plt.xticks(range(6), ['d4', 'd6', 'd8', 'd10', 'd12', 'd20'])
plt.title("Number of Samples per Class (Train)")
plt.show()

# find size of validation set
d4_list = os.listdir('Datasets/val/d4')
d6_list = os.listdir('Datasets/val/d6')
d8_list = os.listdir('Datasets/val/d8')
d10_list = os.listdir('Datasets/val/d10')
d12_list = os.listdir('Datasets/val/d12')
d20_list = os.listdir('Datasets/val/d20')
d4_size = len(d4_list)
d6_size = len(d6_list)
d8_size = len(d8_list)
d10_size = len(d10_list)
d12_size = len(d12_list)
d20_size = len(d20_list)
print("Samples for Validation Set")
print("D4 : ", d4_size)
print("D6 : ", d6_size)
print("D8 : ", d8_size)
print("D10 : ", d10_size)
print("D12 : ", d12_size)
print("D20 : ", d20_size)
```

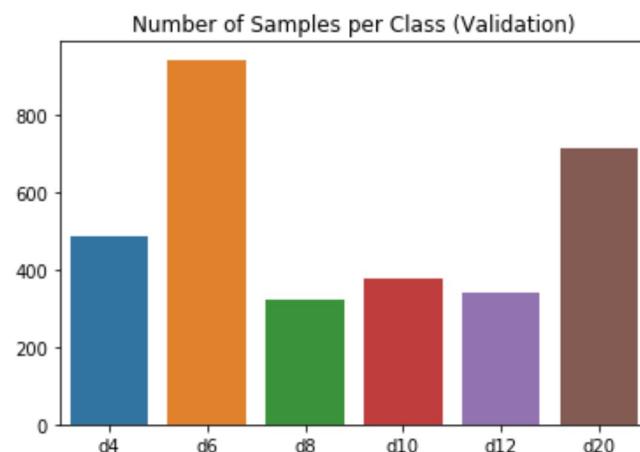
Samples for Training Set

D4 : 1603  
D6 : 3301  
D8 : 1096  
D10 : 1379  
D12 : 1142  
D20 : 2590



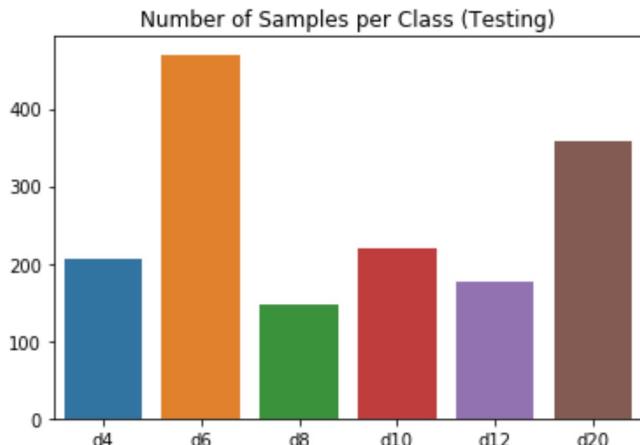
Samples for Validation Set

D4 : 484  
D6 : 942  
D8 : 321  
D10 : 378  
D12 : 338  
D20 : 712



Samples for Testing Set

D4 : 205  
D6 : 470  
D8 : 147  
D10 : 219  
D12 : 176  
D20 : 359



## Load Dataset

```
In [9]: # create image generator
datagenerator = ImageDataGenerator(
    rescale=1./255.,
    rotation_range=40,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.2,
    zoom_range=0.2)
```

```
In [10]: # lists to hold train images and train labels
X_train = []
Y_train = []

# load in images and labels based on how generators label data
# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/train/d4/*.jpg')):
    # append original image
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_train.append(image)
    Y_train.append(3)

    # create some random images, and append to list
    img_tensor = image
    img_tensor = datagenerator.apply_transform(img_tensor, datagenerator
r.get_random_transform(img_tensor.shape))
    X_train.append(img_tensor)
    Y_train.append(3)

# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/train/d6/*.jpg')):
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_train.append(image)
    Y_train.append(4)

# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/train/d8/*.jpg')):
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_train.append(image)
    Y_train.append(5)

    # create some random images, and append to list
    img_tensor = image
    img_tensor = datagenerator.apply_transform(img_tensor, datagenerator
r.get_random_transform(img_tensor.shape))
    X_train.append(img_tensor)
    Y_train.append(5)
```

```
100%|██████████| 1603/1603 [00:4
5<00:00, 35.11it/s]
100%|██████████| 3301/3301 [01:2
6<00:00, 38.18it/s]
100%|██████████| 1096/1096 [00:3
2<00:00, 33.95it/s]
100%|██████████| 1379/1379 [00:4
0<00:00, 34.29it/s]
100%|██████████| 1142/1142 [00:3
1<00:00, 36.07it/s]
100%|██████████| 2590/2590 [00:5
6<00:00, 45.76it/s]
```

```
In [11]: # lists to hold val images and val labels
X_val = []
Y_val = []

# load in images and labels based on how generators label data
# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/val/d4/*.jpg')):
    # append original image
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_val.append(image)
    Y_val.append(3)

    # create some random images, and append to list
    img_tensor = image
    img_tensor = datagenerator.apply_transform(img_tensor, datagenerator
r.get_random_transform(img_tensor.shape))
    X_val.append(img_tensor)
    Y_val.append(3)

# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/val/d6/*.jpg')):
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_val.append(image)
    Y_val.append(4)

# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/val/d8/*.jpg')):
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_val.append(image)
    Y_val.append(5)

    # create some random images, and append to list
    img_tensor = image
    img_tensor = datagenerator.apply_transform(img_tensor, datagenerator
r.get_random_transform(img_tensor.shape))
    X_val.append(img_tensor)
    Y_val.append(5)
```

```
100%| 484/484 [00:1
0<00:00, 44.16it/s]
100%| 942/942 [00:2
0<00:00, 46.51it/s]
100%| 321/321 [00:0
7<00:00, 43.36it/s]
100%| 378/378 [00:0
9<00:00, 39.46it/s]
100%| 338/338 [00:0
7<00:00, 43.08it/s]
100%| 712/712 [00:1
5<00:00, 44.65it/s]
```

```
In [12]: # lists to hold test images and test labels
X_test = []
Y_test = []

# load in images and labels based on how generators label data
# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/test/d4/*.jpg')):
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_test.append(image)
    Y_test.append(3)

# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/test/d6/*.jpg')):
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_test.append(image)
    Y_test.append(4)

# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/test/d8/*.jpg')):
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_test.append(image)
    Y_test.append(5)

# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/test/d10/*.jpg')):
    # load image
    image = plt.imread(file)
    # resize to 100x100
    image = transform.resize(image, (100,100))
    # append image and label to appropriate lists
    X_test.append(image)
    Y_test.append(0)

# for each file in class folder
for file in tqdm.tqdm(glob.glob('Datasets/test/d12/*.jpg')):
    # load image
```

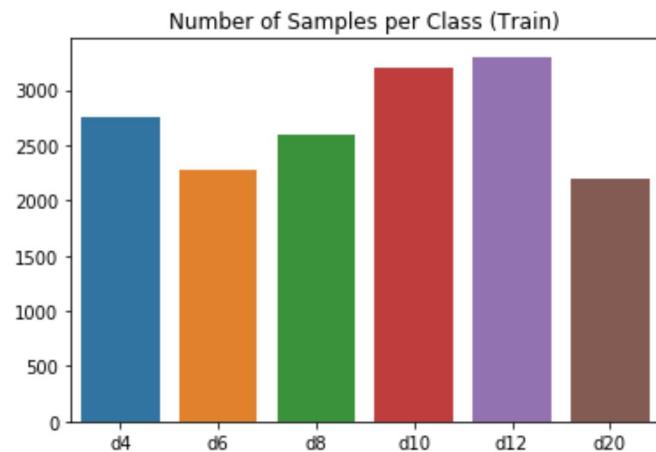
100%| 205/205 [00:0  
4<00:00, 46.94it/s]  
100%| 470/470 [00:1  
1<00:00, 42.44it/s]  
100%| 147/147 [00:0  
3<00:00, 48.76it/s]  
100%| 219/219 [00:0  
4<00:00, 46.32it/s]  
100%| 176/176 [00:0  
4<00:00, 43.55it/s]  
100%| 359/359 [00:0  
7<00:00, 45.32it/s]

```
In [13]: # find size of training set
unique, counts = np.unique(Y_train, return_counts=True)
d4_size, d6_size, d8_size, d10_size, d12_size, d20_size = counts
print("Samples for Training Set")
print("D4 : ", d4_size)
print("D6 : ", d6_size)
print("D8 : ", d8_size)
print("D10 : ", d10_size)
print("D12 : ", d12_size)
print("D20 : ", d20_size)
train_size = d4_size + d6_size + d8_size + d10_size + d12_size + d20_size
sns.barplot([0,1,2,3,4,5], [d4_size, d6_size, d8_size, d10_size, d12_size, d20_size])
plt.xticks(range(6), ['d4', 'd6', 'd8', 'd10', 'd12', 'd20'])
plt.title("Number of Samples per Class (Train)")
plt.show()

# find size of validation set
unique, counts = np.unique(Y_val, return_counts=True)
# find size of training set
d4_size, d6_size, d8_size, d10_size, d12_size, d20_size = counts
print("Samples for Validation Set")
print("D4 : ", d4_size)
print("D6 : ", d6_size)
print("D8 : ", d8_size)
print("D10 : ", d10_size)
print("D12 : ", d12_size)
print("D20 : ", d20_size)
validation_size = d4_size + d6_size + d8_size + d10_size + d12_size + d20_size
sns.barplot([0,1,2,3,4,5], [d4_size, d6_size, d8_size, d10_size, d12_size, d20_size])
plt.xticks(range(6), ['d4', 'd6', 'd8', 'd10', 'd12', 'd20'])
plt.title("Number of Samples per Class (Validation)")
plt.show()
```

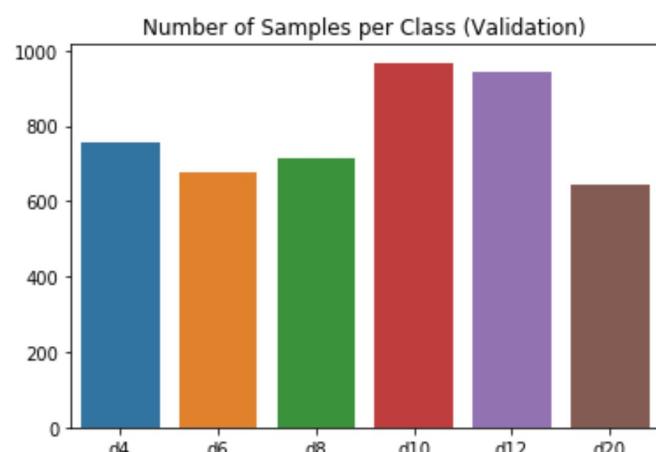
Samples for Training Set

D4 : 2758  
D6 : 2284  
D8 : 2590  
D10 : 3206  
D12 : 3301  
D20 : 2192



Samples for Validation Set

D4 : 756  
D6 : 676  
D8 : 712  
D10 : 968  
D12 : 942  
D20 : 642



In [14]: `from sklearn.preprocessing import OneHotEncoder`

```
In [15]: # convert class labels to categorical
encoder = OneHotEncoder(sparse=False)
encoder.fit(np.expand_dims(Y_train, axis=1))
Y_train_cat = encoder.transform(np.expand_dims(Y_train, axis=1))
Y_val_cat = encoder.transform(np.expand_dims(Y_val, axis=1))
Y_test_cat = encoder.transform(np.expand_dims(Y_test, axis=1))
```

## Build/Train Model

```
In [16]: # build the model
model = Sequential()
model.add(Conv2D(32, (3, 3), kernel_initializer='glorot_uniform', input_shape=(100, 100, 3)))
#model.add(BatchNormalization())
model.add(Activation('relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Dropout(rate=0.2))
model.add(Conv2D(64, (3, 3), kernel_initializer='glorot_uniform'))
#model.add(BatchNormalization())
model.add(Activation('relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Dropout(rate=0.2))
model.add(Conv2D(128, (3, 3), kernel_initializer='glorot_uniform'))
#model.add(BatchNormalization())
model.add(Activation('relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Dropout(rate=0.2))
model.add(Conv2D(128, (3, 3), kernel_initializer='glorot_uniform'))
#model.add(BatchNormalization())
model.add(Activation('relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Dropout(rate=0.2))
model.add(Flatten())
model.add(Dense(512, kernel_initializer='glorot_uniform', use_bias=False))
model.add(Activation('relu'))
model.add(BatchNormalization())
model.add(Dropout(rate=0.2))
model.add(Dense(6, kernel_initializer='glorot_uniform'))
model.add(Activation('softmax'))

In [17]: # compile the model to use binary crossentropy and use RMSProp optimizer
model.compile(loss='categorical_crossentropy', optimizer='adagrad', metrics=['acc'])
```

```
In [18]: history = model.fit(X_train,  
                           Y_train_cat,  
                           batch_size=batch_size,  
                           epochs=num_epochs,  
                           verbose=1, shuffle=True, validation_data=[X_val, Y_  
                           val_cat])
```

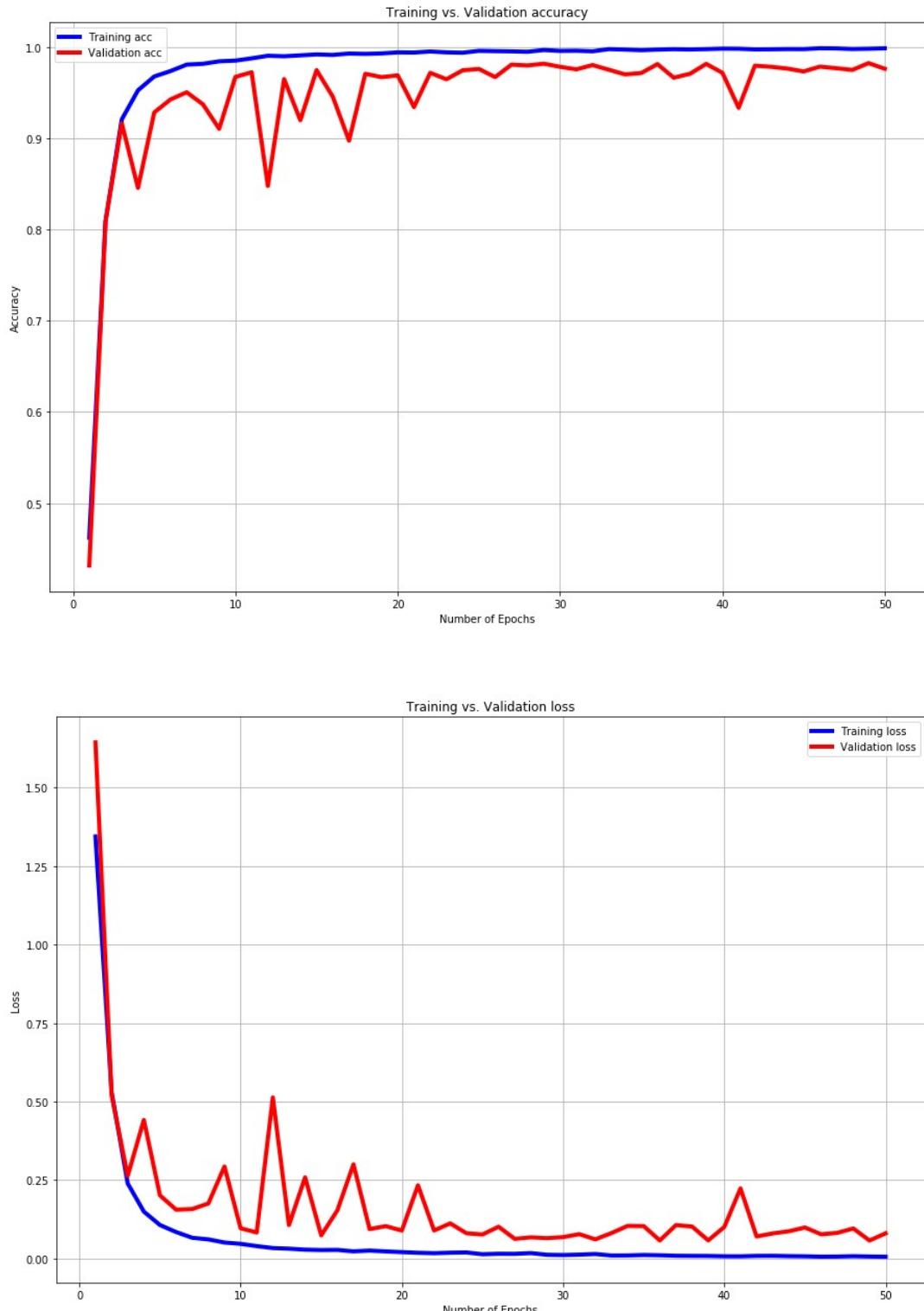
```
Train on 16331 samples, validate on 4696 samples
Epoch 1/50
16331/16331 [=====] - 15s 890us/step - loss: 1.3444 - acc: 0.4623 - val_loss: 1.6442 - val_acc: 0.4319
Epoch 2/50
16331/16331 [=====] - 13s 774us/step - loss: 0.5306 - acc: 0.8094 - val_loss: 0.5210 - val_acc: 0.8090
Epoch 3/50
16331/16331 [=====] - 13s 775us/step - loss: 0.2390 - acc: 0.9206 - val_loss: 0.2634 - val_acc: 0.9165
Epoch 4/50
16331/16331 [=====] - 13s 774us/step - loss: 0.1495 - acc: 0.9525 - val_loss: 0.4415 - val_acc: 0.8456
Epoch 5/50
16331/16331 [=====] - 13s 772us/step - loss: 0.1067 - acc: 0.9677 - val_loss: 0.2011 - val_acc: 0.9282
Epoch 6/50
16331/16331 [=====] - 13s 774us/step - loss: 0.0843 - acc: 0.9736 - val_loss: 0.1556 - val_acc: 0.9425
Epoch 7/50
16331/16331 [=====] - 13s 774us/step - loss: 0.0660 - acc: 0.9807 - val_loss: 0.1576 - val_acc: 0.9504
Epoch 8/50
16331/16331 [=====] - 13s 774us/step - loss: 0.0610 - acc: 0.9816 - val_loss: 0.1753 - val_acc: 0.9372
Epoch 9/50
16331/16331 [=====] - 13s 772us/step - loss: 0.0509 - acc: 0.9843 - val_loss: 0.2931 - val_acc: 0.9103
Epoch 10/50
16331/16331 [=====] - 13s 772us/step - loss: 0.0468 - acc: 0.9851 - val_loss: 0.0964 - val_acc: 0.9672
Epoch 11/50
16331/16331 [=====] - 13s 773us/step - loss: 0.0395 - acc: 0.9876 - val_loss: 0.0828 - val_acc: 0.9723
Epoch 12/50
16331/16331 [=====] - 13s 770us/step - loss: 0.0333 - acc: 0.9904 - val_loss: 0.5131 - val_acc: 0.8477
Epoch 13/50
16331/16331 [=====] - 13s 771us/step - loss: 0.0314 - acc: 0.9898 - val_loss: 0.1065 - val_acc: 0.9649
Epoch 14/50
16331/16331 [=====] - 13s 774us/step - loss: 0.0283 - acc: 0.9908 - val_loss: 0.2587 - val_acc: 0.9197
Epoch 15/50
16331/16331 [=====] - 13s 773us/step - loss: 0.0270 - acc: 0.9919 - val_loss: 0.0737 - val_acc: 0.9747
Epoch 16/50
16331/16331 [=====] - 13s 774us/step - loss: 0.0275 - acc: 0.9913 - val_loss: 0.1533 - val_acc: 0.9455
Epoch 17/50
16331/16331 [=====] - 13s 775us/step - loss: 0.0228 - acc: 0.9928 - val_loss: 0.3001 - val_acc: 0.8974
Epoch 18/50
16331/16331 [=====] - 13s 774us/step - loss: 0.0254 - acc: 0.9925 - val_loss: 0.0938 - val_acc: 0.9706
Epoch 19/50
16331/16331 [=====] - 13s 773us/step - loss: 0.0226 - acc: 0.9930 - val_loss: 0.1031 - val_acc: 0.9670
Epoch 20/50
16331/16331 [=====] - 13s 774us/step - loss: 0.0203 - acc: 0.9941 - val_loss: 0.0891 - val_acc: 0.9689
Epoch 21/50
16331/16331 [=====] - 13s 773us/step - loss: 0.0182 - acc: 0.9939 - val_loss:
```

```
In [19]: # save the model for future use  
model.save('dice_relu_softmax_Adagrad_less_steps.h5')
```

## Evaluate Performance

```
In [20]: #model.load_weights('cats_and_dogs_relu_sigmoid_Adam.h5')  
# Evaluate classifier with test image generator  
evaluation = model.evaluate(X_test, Y_test_cat, verbose=1)  
print("Test Loss: %.4f" % evaluation[0])  
print("Test Accuracy: %.4f" % (evaluation[1]*100))  
  
1576/1576 [=====] - 1s 425us/step  
Test Loss: 0.0588  
Test Accuracy: 99.1117
```

```
In [21]: # plot accuracy and loss plots
acc = history.history['acc']
val_acc = history.history['val_acc']
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs = range(1, len(acc) + 1)
plt.figure(facecolor='w', figsize=(15,10))
plt.plot(epochs, acc, 'b', label='Training acc', lw=4)
plt.plot(epochs, val_acc, 'r', label='Validation acc', lw=4)
plt.title('Training vs. Validation accuracy')
plt.xlabel('Number of Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.grid()
plt.figure(facecolor='w', figsize=(15,10))
plt.plot(epochs, loss, 'b', label='Training loss', lw=4)
plt.plot(epochs, val_loss, 'r', label='Validation loss', lw=4)
plt.title('Training vs. Validation loss')
plt.xlabel('Number of Epochs')
plt.ylabel('Loss')
plt.legend()
plt.grid()
plt.show()
```



```
In [22]: # shuffle dataset manually because model did it before
X_test, Y_test_cat = shuffle(X_test, Y_test_cat)
# predict labels
predictions = model.predict(X_test)
```

```
In [23]: from sklearn.metrics import r2_score, confusion_matrix, classification_
report
from sklearn.metrics import mean_squared_error, roc_curve, auc, confusi
on_matrix
from scipy import interp
from itertools import cycle
```

```
In [24]: # Compute ROC curve and ROC area for each class
fpr = dict()
tpr = dict()
roc_auc = dict()
for i in range(6):
    fpr[i], tpr[i], _ = roc_curve(Y_test_cat[:, i], predictions[:, i])
    roc_auc[i] = auc(fpr[i], tpr[i])

# Compute micro-average ROC curve and ROC area
fpr["micro"], tpr["micro"], _ = roc_curve(Y_test_cat.ravel(), predictions.ravel())
roc_auc["micro"] = auc(fpr["micro"], tpr["micro"])

# First aggregate all false positive rates
all_fpr = np.unique(np.concatenate([fpr[i] for i in range(6)]))

# Then interpolate all ROC curves at this points
mean_tpr = np.zeros_like(all_fpr)
for i in range(6):
    mean_tpr += interp(all_fpr, fpr[i], tpr[i])

# Finally average it and compute AUC
mean_tpr /= 6

fpr["macro"] = all_fpr
tpr["macro"] = mean_tpr
roc_auc["macro"] = auc(fpr["macro"], tpr["macro"])

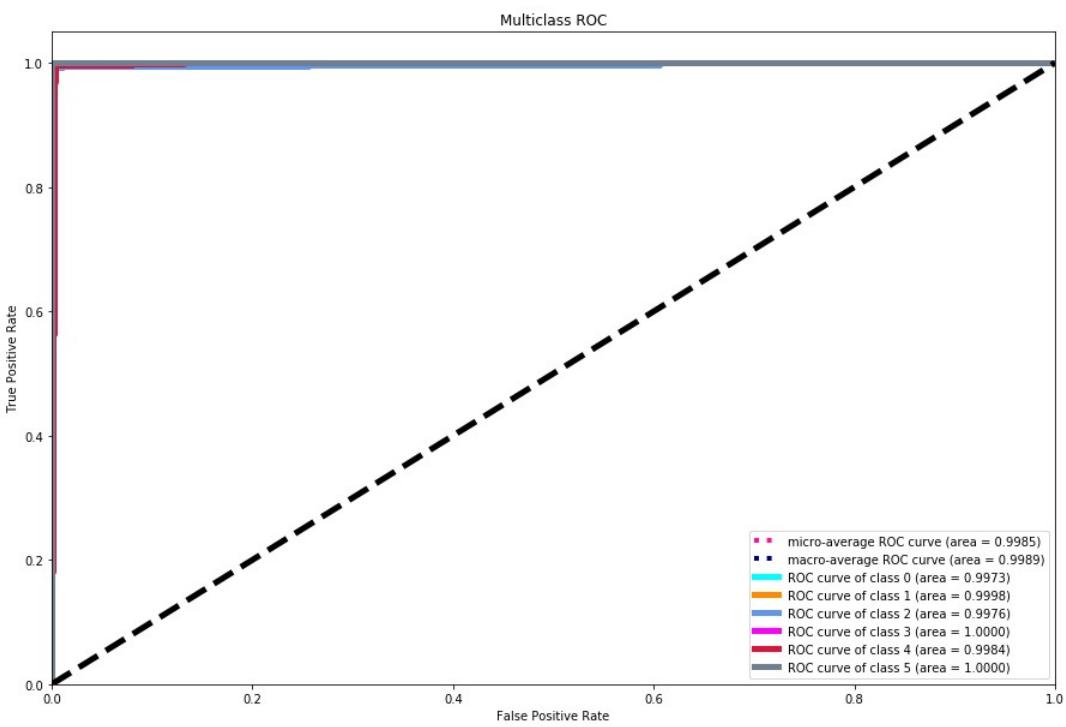
# set line width of graphs
lw = 5

# Plot all ROC curves
plt.figure(figsize=(15,10), facecolor='w')
plt.plot(fpr["micro"], tpr["micro"],
          label='micro-average ROC curve (area = {0:0.4f})'.format(roc_auc["micro"]),
          color='deeppink', linestyle=':', linewidth=4)

plt.plot(fpr["macro"], tpr["macro"],
          label='macro-average ROC curve (area = {0:0.4f})'.format(roc_auc["macro"]),
          color='navy', linestyle=':', linewidth=4)

colors = cycle(['aqua', 'darkorange', 'cornflowerblue', 'fuchsia', 'crimson', 'slategray'])
for i, color in zip(range(6), colors):
    plt.plot(fpr[i], tpr[i], color=color, lw=lw,
              label='ROC curve of class {0} (AUC = {1:0.4f})'.format(i, roc_auc[i]))
```

C:\Users\kluse\Anaconda3\envs\MLearning\lib\site-packages\ipykernel\_launcher.py:19: DeprecationWarning: scipy.interp is deprecated and will be removed in SciPy 2.0.0, use numpy.interp instead



```
In [25]: # plot confusion matrix
plt.figure(figsize=(15,10), facecolor='w')
numerical_Y_test = encoder.inverse_transform(Y_test_cat)[:,0]
numerical_predictions = encoder.inverse_transform(predictions)[:,0]
sns.heatmap(confusion_matrix(numerical_Y_test, numerical_predictions, normalize='all'), fmt='.4f', annot=True)
```

```
<matplotlib.axes._subplots.AxesSubplot at 0x1f5b133ff28>
```



```
In [26]: # print classification report to find Precision, Recall, and F1-score
print(classification_report(numerical_Y_test, numerical_predictions, digits=4))
```

	precision	recall	f1-score	support
0	0.9776	0.9954	0.9864	219
1	0.9778	1.0000	0.9888	176
2	1.0000	0.9861	0.9930	359
3	1.0000	0.9707	0.9851	205
4	0.9894	0.9957	0.9926	470
5	1.0000	1.0000	1.0000	147
accuracy			0.9911	1576
macro avg	0.9908	0.9913	0.9910	1576
weighted avg	0.9913	0.9911	0.9911	1576

## Visualize Predictions

```
In [27]: # lists to hold some correct and incorrectly classified images
correct_indices = []
incorrect_indices = []

for i in range(numerical_Y_test.shape[0]):
    # check if we have a correct match if so append to list
    if(numerical_Y_test[i] == numerical_predictions[i]):
        correct_indices.append(i)
    # stop when we reach 12 examples
    if(len(correct_indices) == 12):
        break

for i in range(numerical_Y_test.shape[0]):
    # check if we have a incorrect match if so append to list
    if(numerical_Y_test[i] != numerical_predictions[i]):
        incorrect_indices.append(i)
    # stop when we reach 12 examples
    if(len(incorrect_indices) == 12):
        break
```

```
In [28]: index = 1
plt.figure(figsize=(6,24))
for correct, incorrect in zip(correct_indices, incorrect_indices):
    plt.subplot(12, 2, index)
    plt.imshow(X_test[correct])
    plt.title("Actual = %s Prediction = %s" % (numerical_Y_test[correct], numerical_predictions[correct]))
    plt.xticks([])
    plt.yticks([])
    plt.subplot(12, 2, index+1)
    plt.imshow(X_test[incorrect])
    plt.title("Actual = %s Prediction = %s" % (numerical_Y_test[incorrect], numerical_predictions[incorrect]))
    plt.xticks([])
    plt.yticks([])
    index = index + 2
```

Actual = 5 Prediction = 5	
Actual = 2 Prediction = 4	
Actual = 4 Prediction = 4	
Actual = 3 Prediction = 0	
Actual = 0 Prediction = 0	
Actual = 4 Prediction = 0	
Actual = 0 Prediction = 0	
Actual = 3 Prediction = 1	
Actual = 2 Prediction = 2	
Actual = 2 Prediction = 4	
Actual = 4 Prediction = 4	
Actual = 0 Prediction = 1	
Actual = 1 Prediction = 1	
Actual = 2 Prediction = 1	
Actual = 5 Prediction = 5	
Actual = 2 Prediction = 4	
Actual = 3 Prediction = 3	
Actual = 4 Prediction = 0	
Actual = 2 Prediction = 2	
Actual = 3 Prediction = 0	

## Visual Activation Maps

```
In [29]: from keras.preprocessing import image
import numpy as np

#create list of randomly augmented images of dice
dice_images = []

for i in range(2):
    img = image.load_img("Datasets/val/d4/13136.jpg", target_size=(100,
100))
    img_tensor = image.img_to_array(img)
    img_tensor = datagenerator.apply_transform(img_tensor, datagenerator
r.get_random_transform(img_tensor.shape))
    img_tensor = np.expand_dims(img_tensor, axis=0)
    img_tensor/=255
    dice_images.append(img_tensor)

for i in range(2):
    img = image.load_img("Datasets/val/d6/13123.jpg", target_size=(100,
100))
    img_tensor = image.img_to_array(img)
    img_tensor = datagenerator.apply_transform(img_tensor, datagenerator
r.get_random_transform(img_tensor.shape))
    img_tensor = np.expand_dims(img_tensor, axis=0)
    img_tensor/=255
    dice_images.append(img_tensor)

for i in range(2):
    img = image.load_img("Datasets/val/d8/13541.jpg", target_size=(100,
100))
    img_tensor = image.img_to_array(img)
    img_tensor = datagenerator.apply_transform(img_tensor, datagenerator
r.get_random_transform(img_tensor.shape))
    img_tensor = np.expand_dims(img_tensor, axis=0)
    img_tensor/=255
    dice_images.append(img_tensor)

for i in range(2):
    img = image.load_img("Datasets/val/d12/15317.jpg", target_size=(10
0,100))
    img_tensor = image.img_to_array(img)
    img_tensor = datagenerator.apply_transform(img_tensor, datagenerator
r.get_random_transform(img_tensor.shape))
    img_tensor = np.expand_dims(img_tensor, axis=0)
    img_tensor/=255
    dice_images.append(img_tensor)

for i in range(2):
    img = image.load_img("Datasets/val/d17/220/14000.jpg", target_size=(10
0,100))
    img_tensor = image.img_to_array(img)
    img_tensor = datagenerator.apply_transform(img_tensor, datagenerator
r.get_random_transform(img_tensor.shape))
    img_tensor = np.expand_dims(img_tensor, axis=0)
    img_tensor/=255
    dice_images.append(img_tensor)
```

```
In [30]: from keras import models  
layer_outputs = [layer.output for layer in model.layers]  
activation_model = models.Model(inputs=model.input, outputs=layer_outputs)
```

```
In [31]: import numpy as np
import time

for img in dice_images:
    plt.figure(facecolor='w')
    plt.title("Original Image")
    plt.imshow(img[0])
    activations = activation_model.predict(img)
    layer_names = [layer.name for layer in model.layers]
    images_per_row = 8

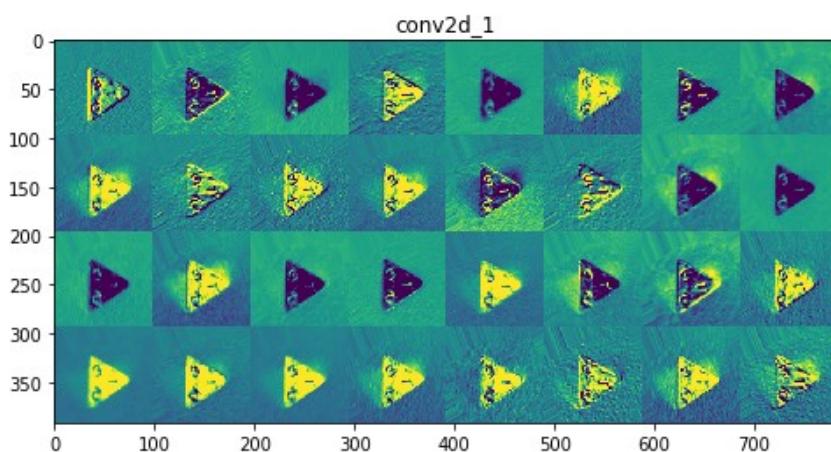
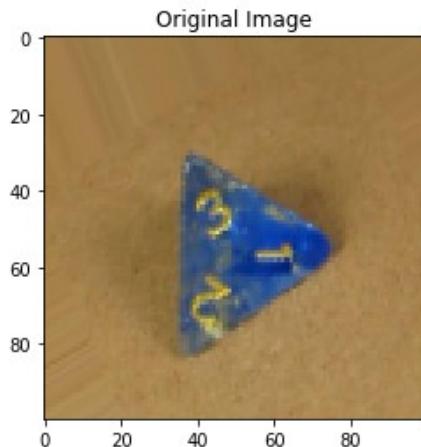
    for layer_name, layer_activation in zip(layer_names, activations):
        # skip none convolutional layers
        if(layer_name.find('conv') == -1):
            continue
        n_features = layer_activation.shape[-1]

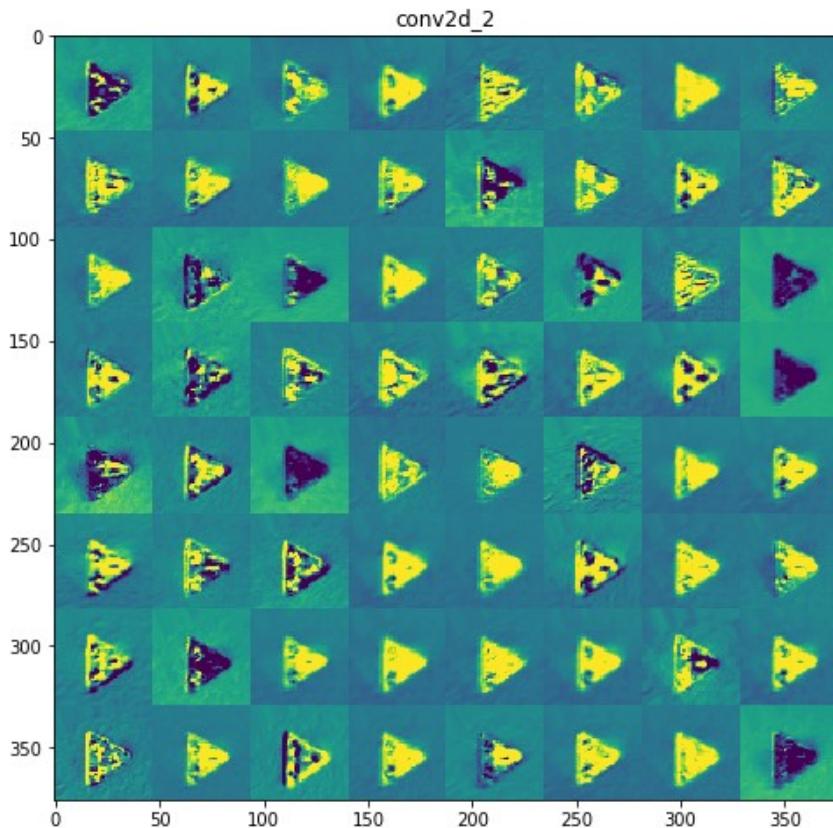
        size = layer_activation.shape[1]

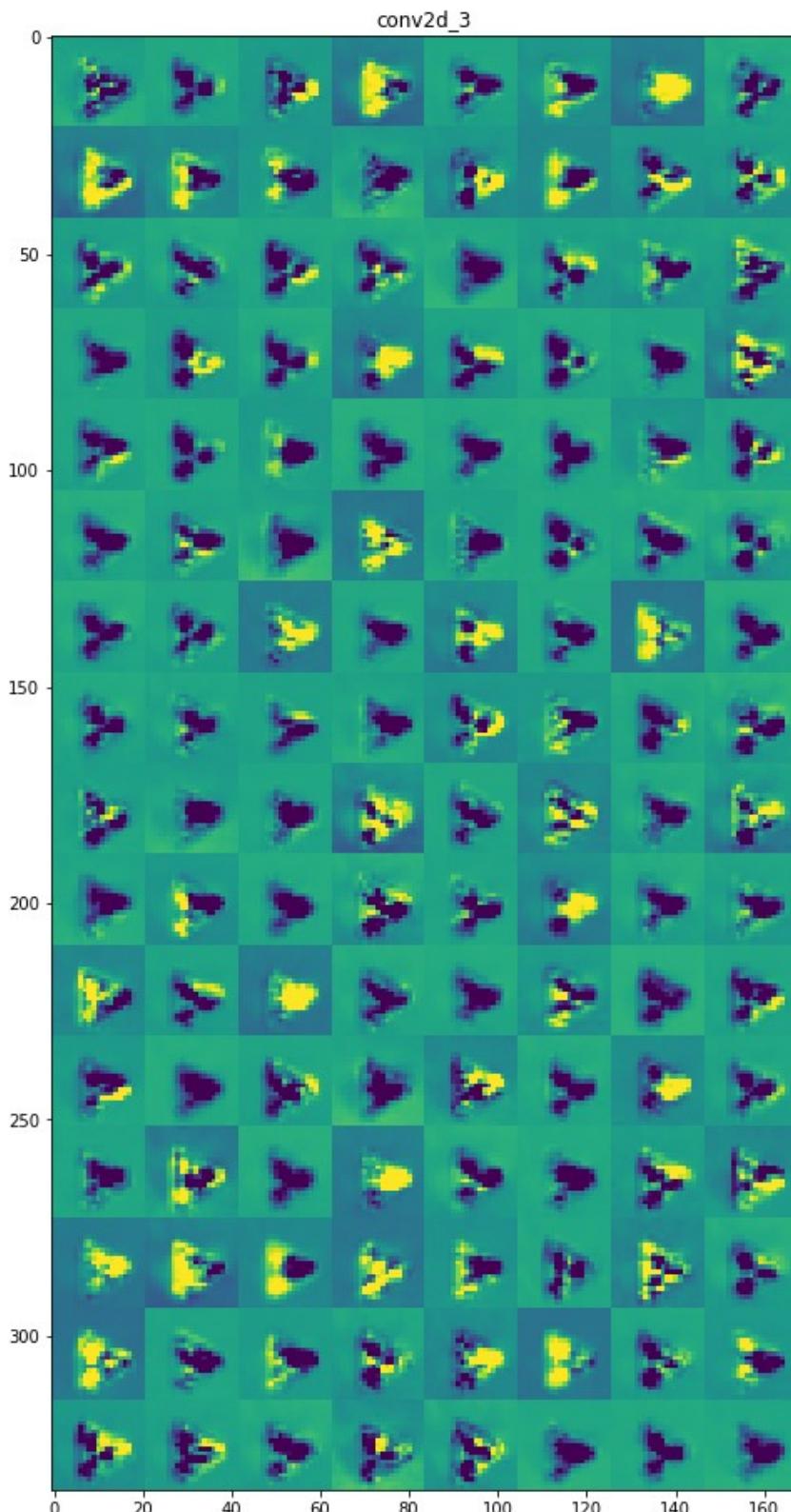
        n_cols = n_features // images_per_row
        display_grid = np.zeros((size * n_cols, images_per_row * size))

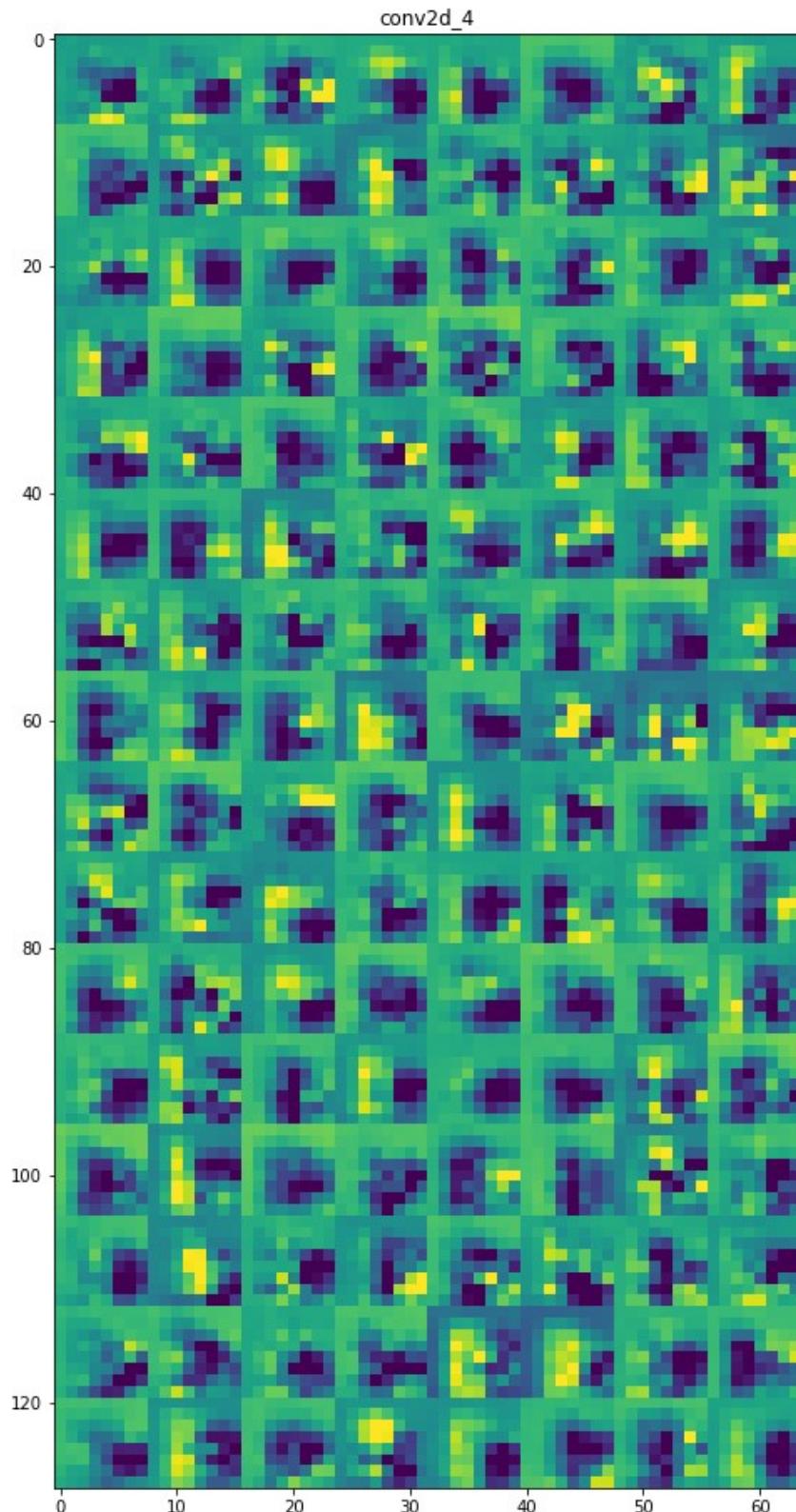
        for col in range(n_cols):
            for row in range(images_per_row):
                channel_image = layer_activation[0, :, :, col * images_per_row + row]
                channel_image -= channel_image.mean()
                channel_image /= channel_image.std()
                channel_image *= 64
                channel_image += 128
                channel_image = np.clip(channel_image, 0, 255).astype('uint8')
                display_grid[col * size : (col + 1) * size, row * size : (row + 1) * size] = channel_image

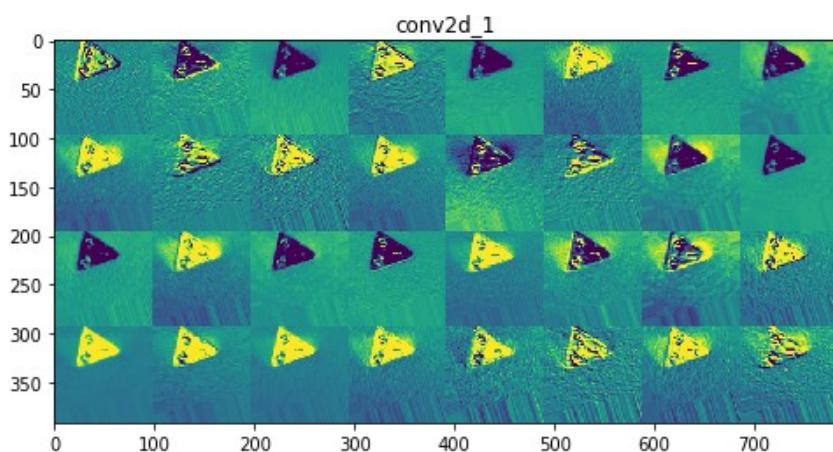
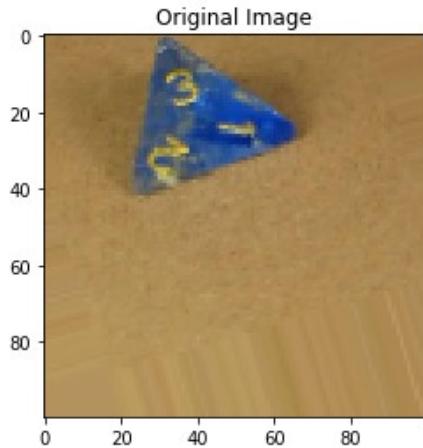
        scale = 1. / size
        plt.figure(figsize=(scale * display_grid.shape[1], scale * display_grid.shape[0]), facecolor='w')
        plt.title(layer_name)
        plt.grid(False)
        plt.imshow(display_grid, aspect='auto', cmap='viridis')
        plt.show()
```

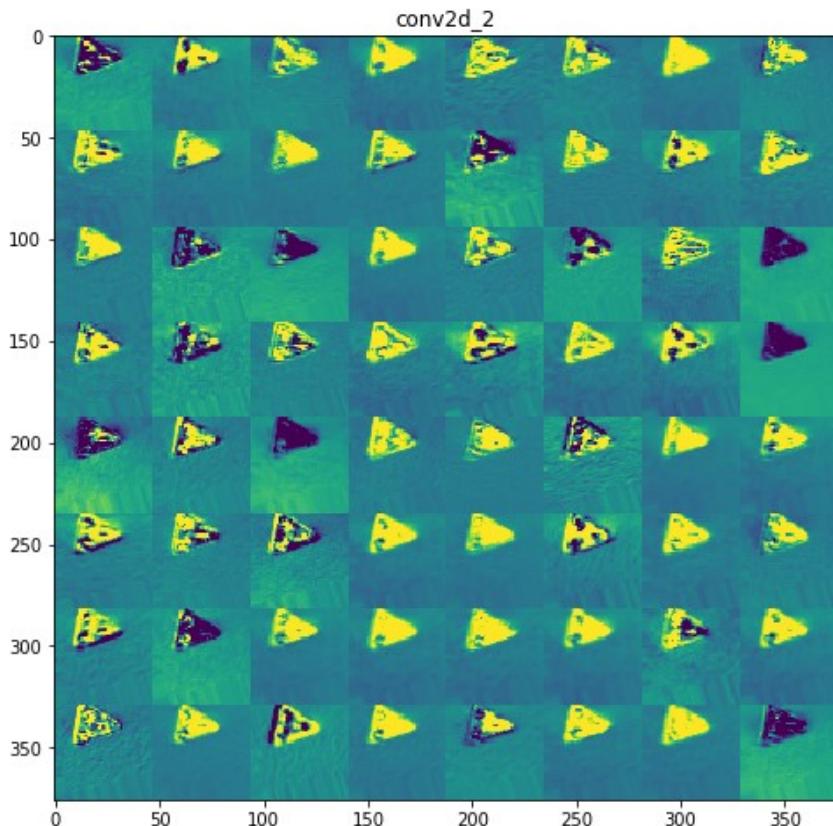


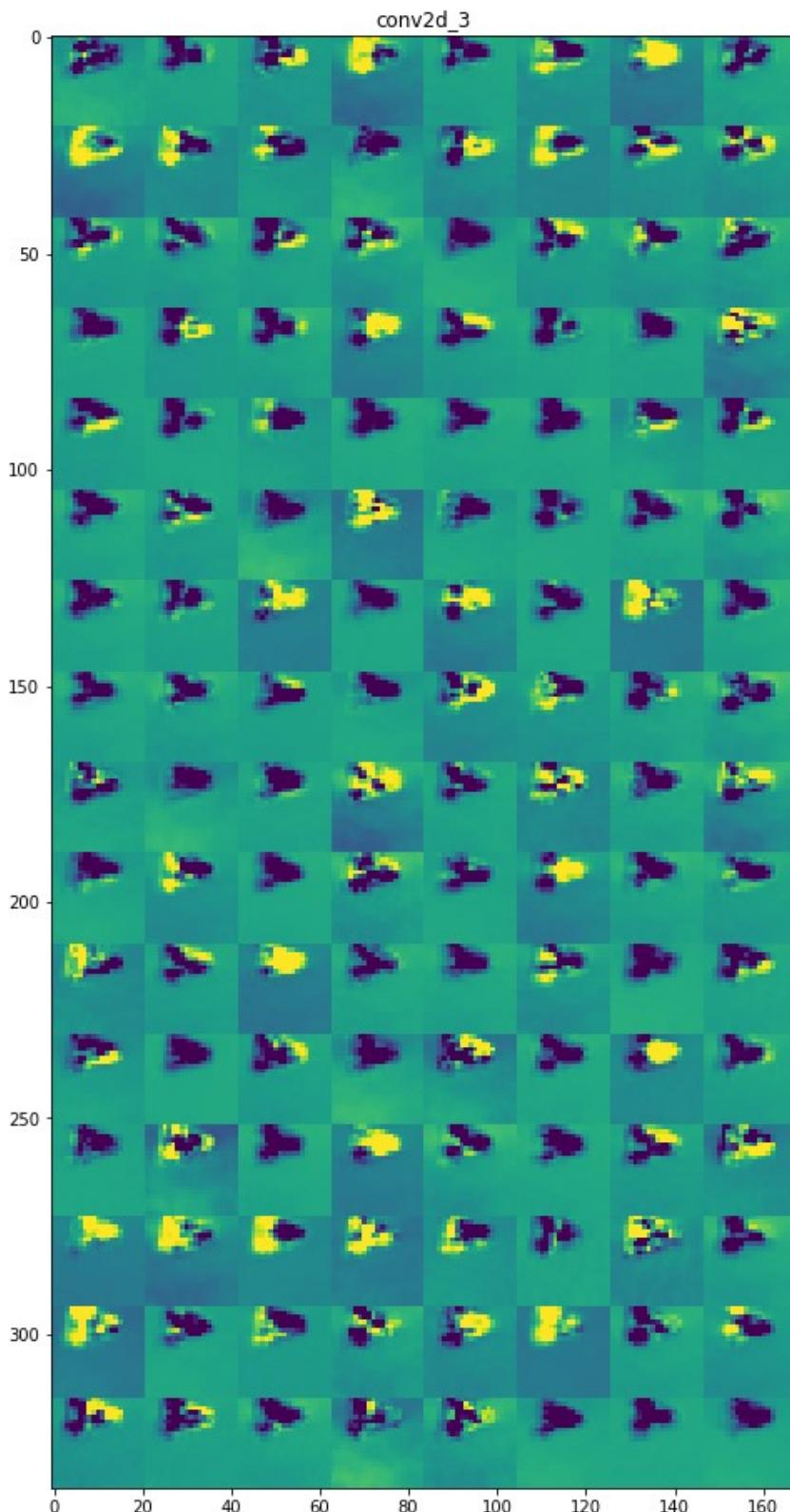


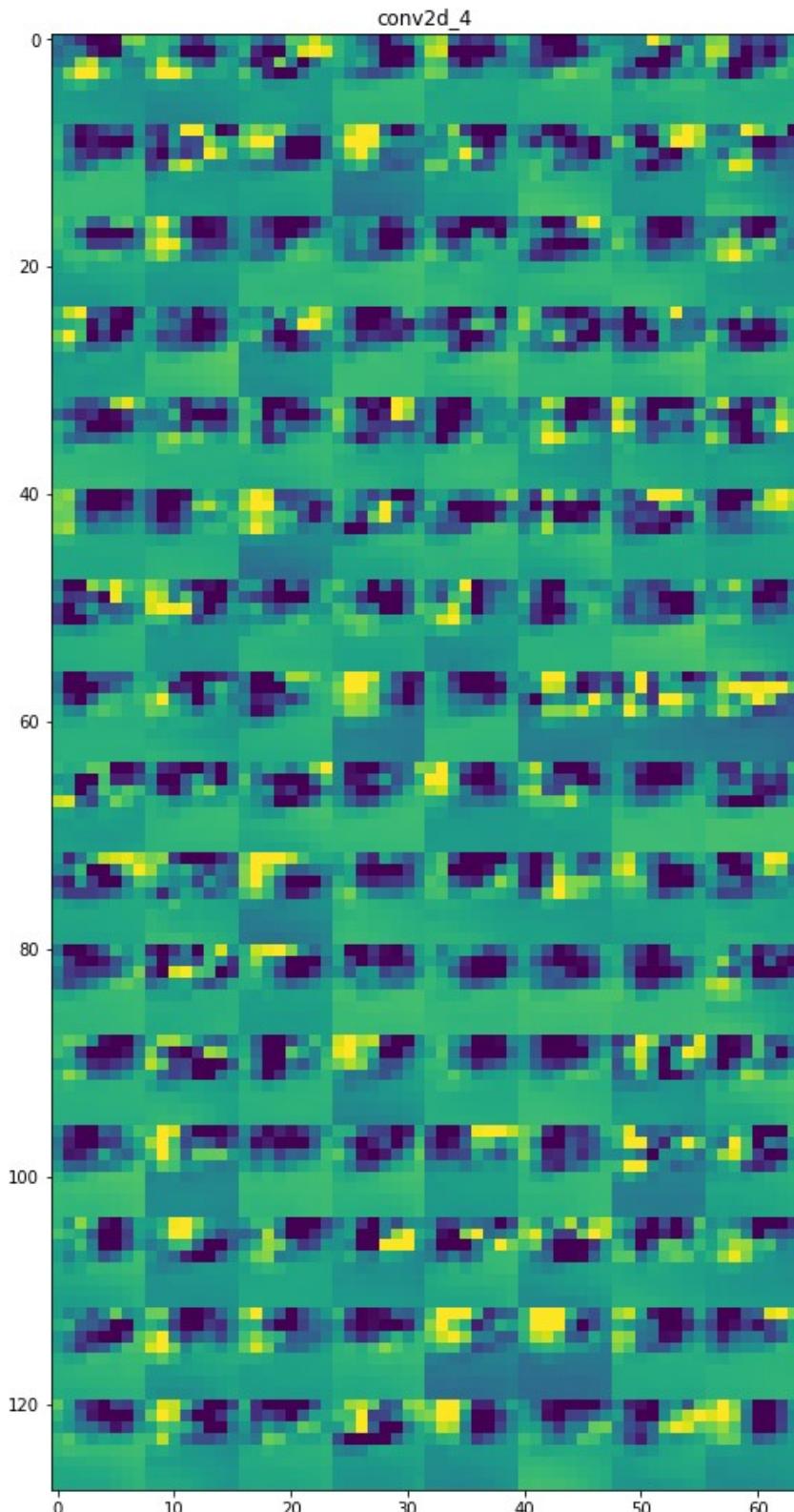


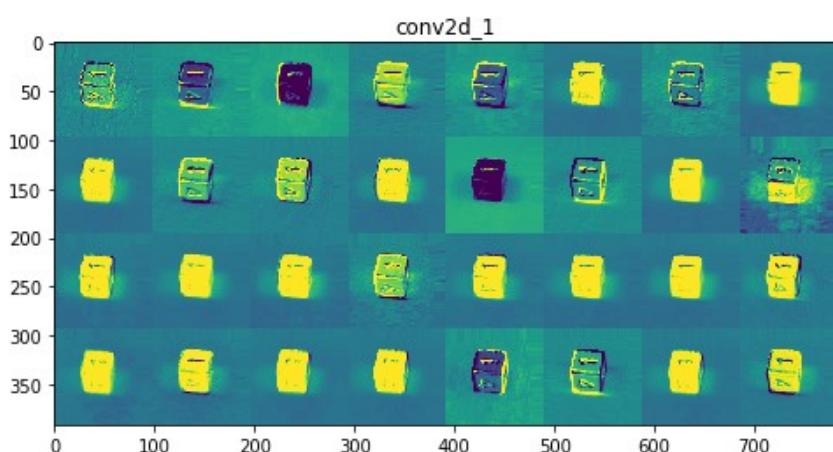
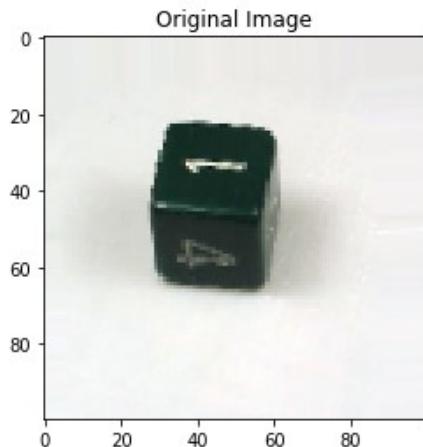


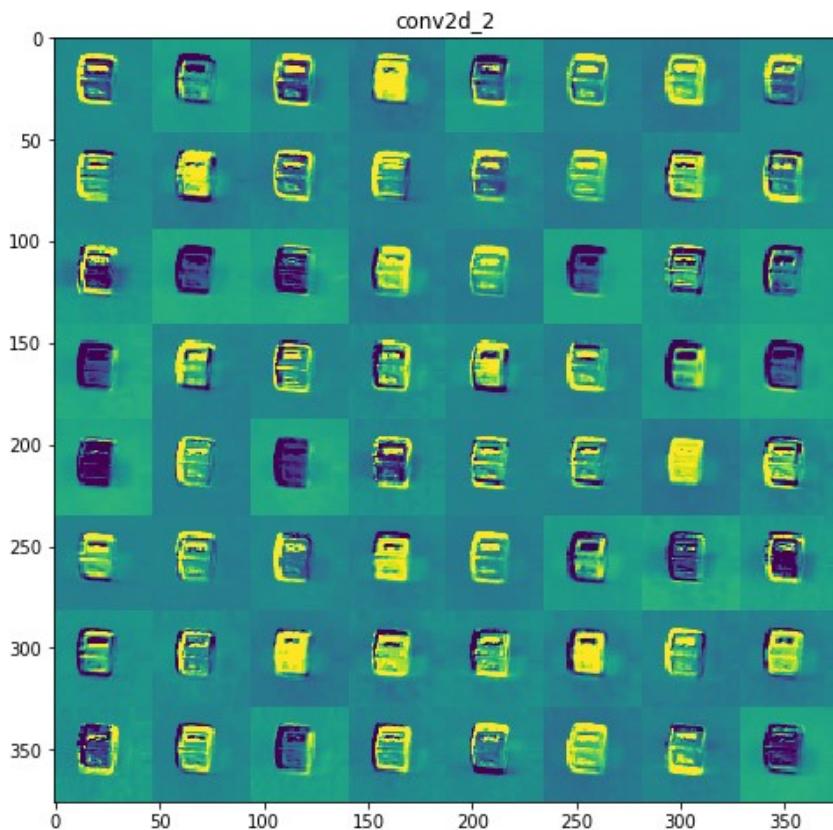


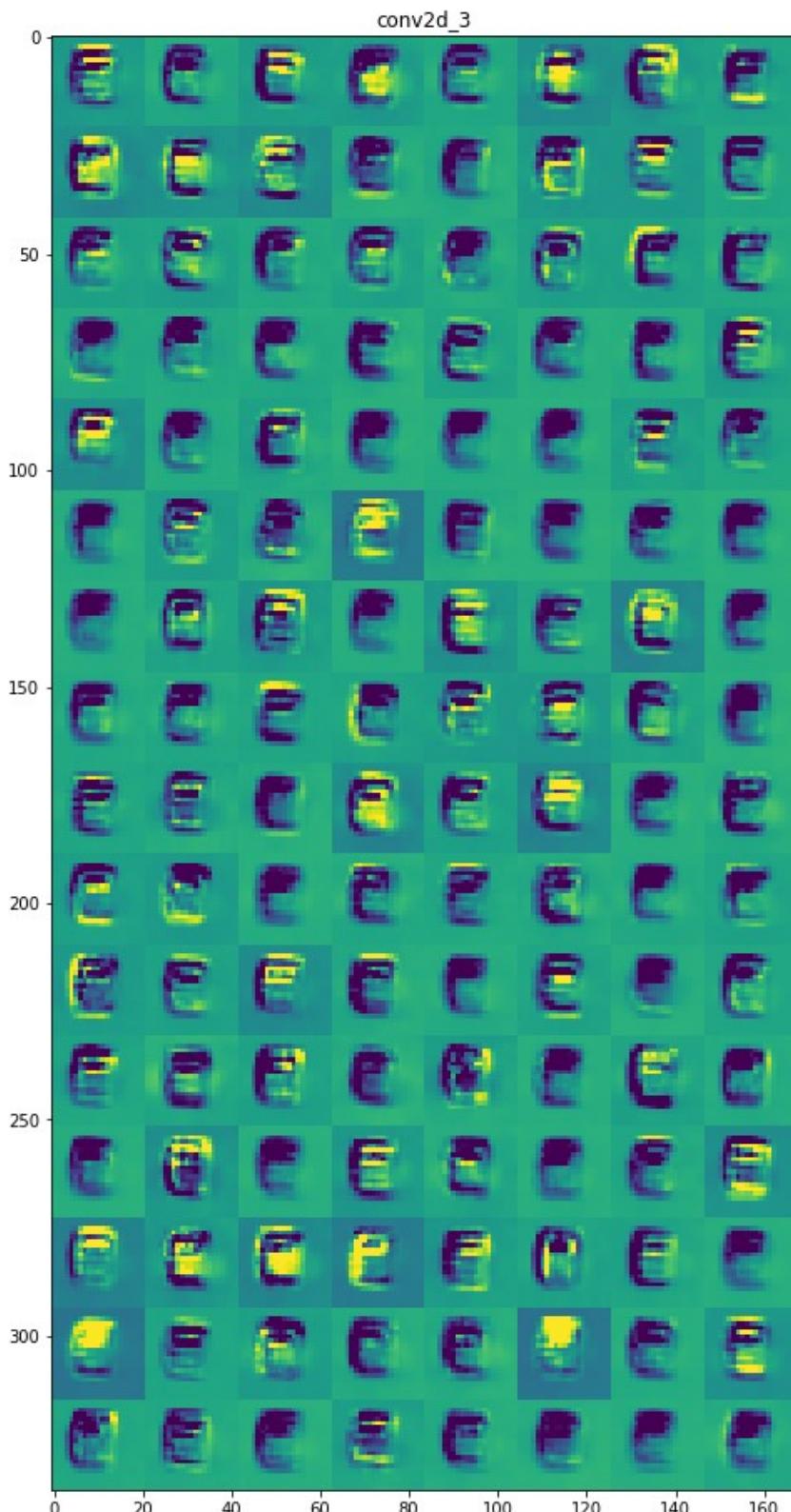


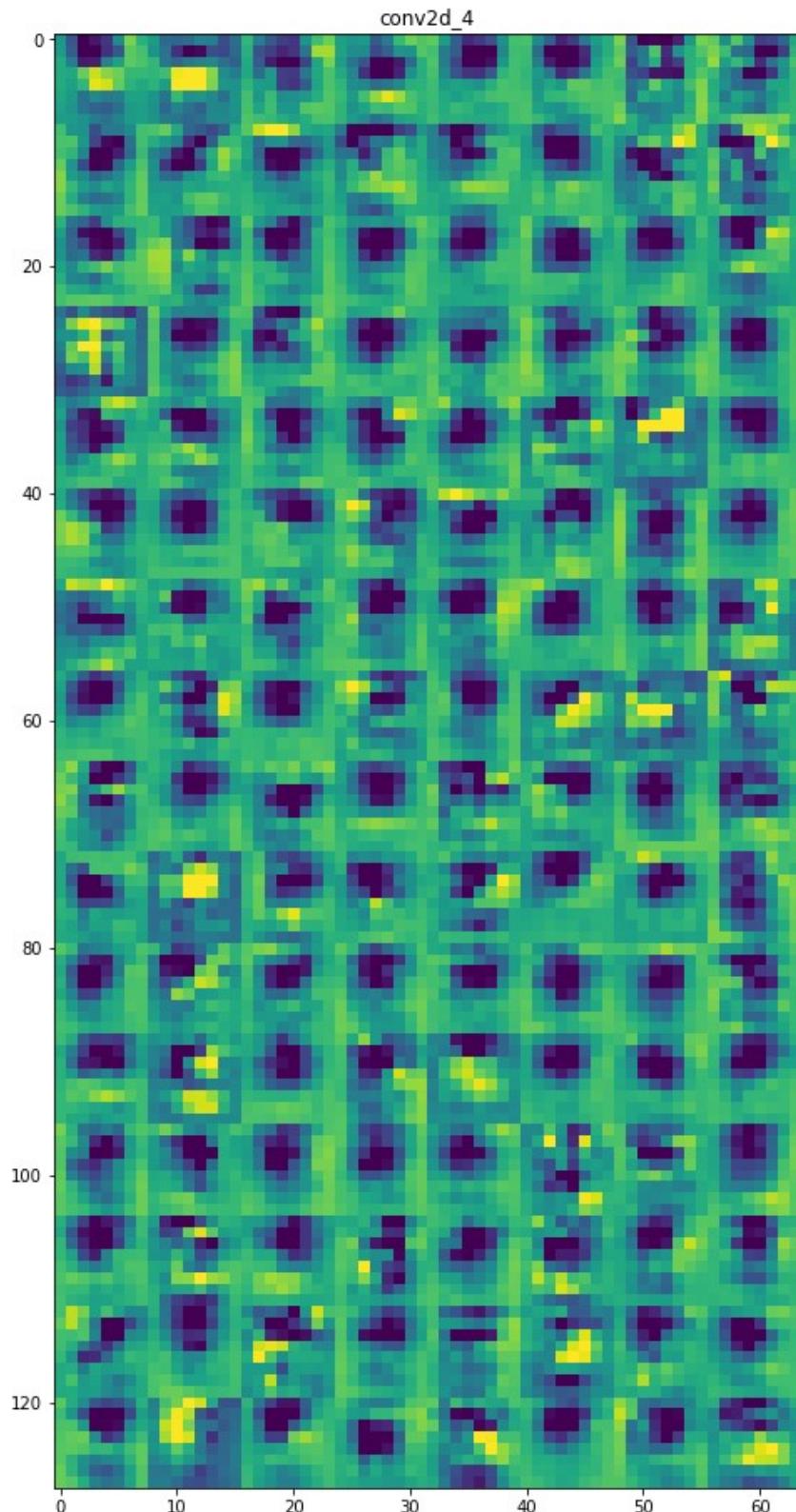


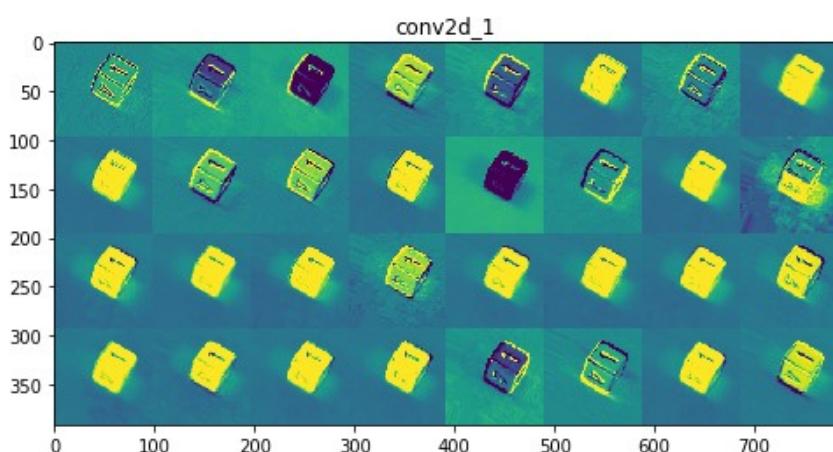
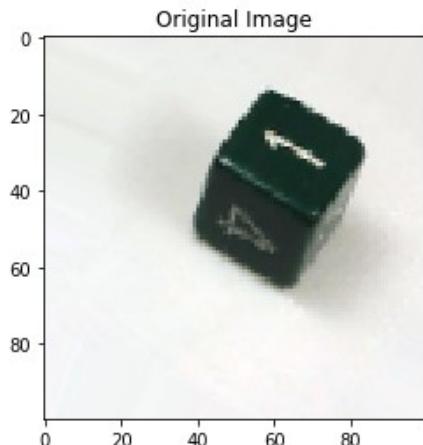


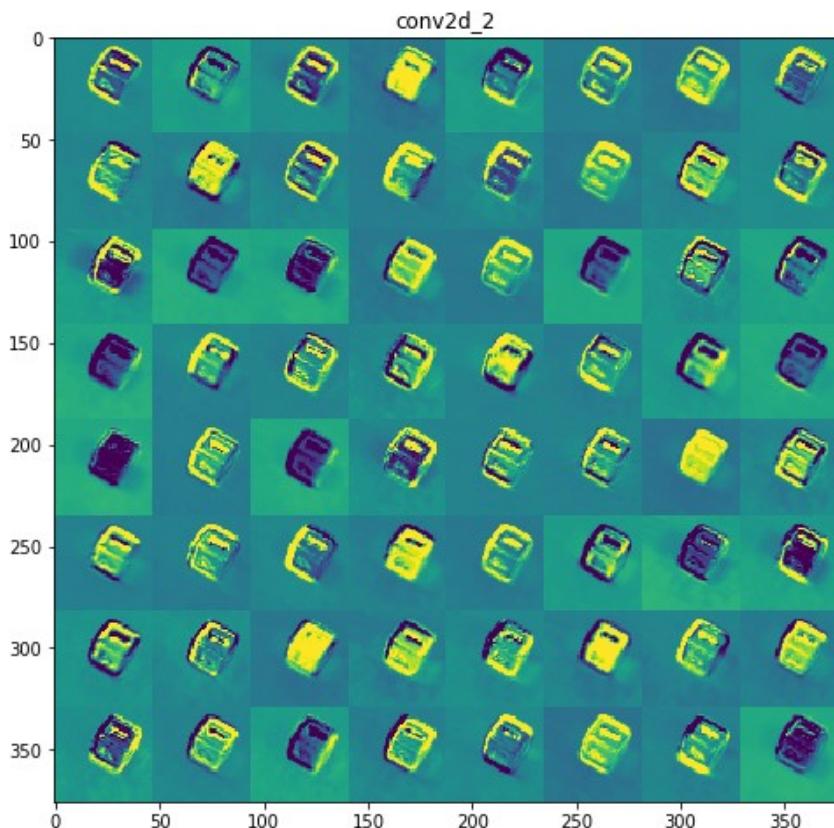


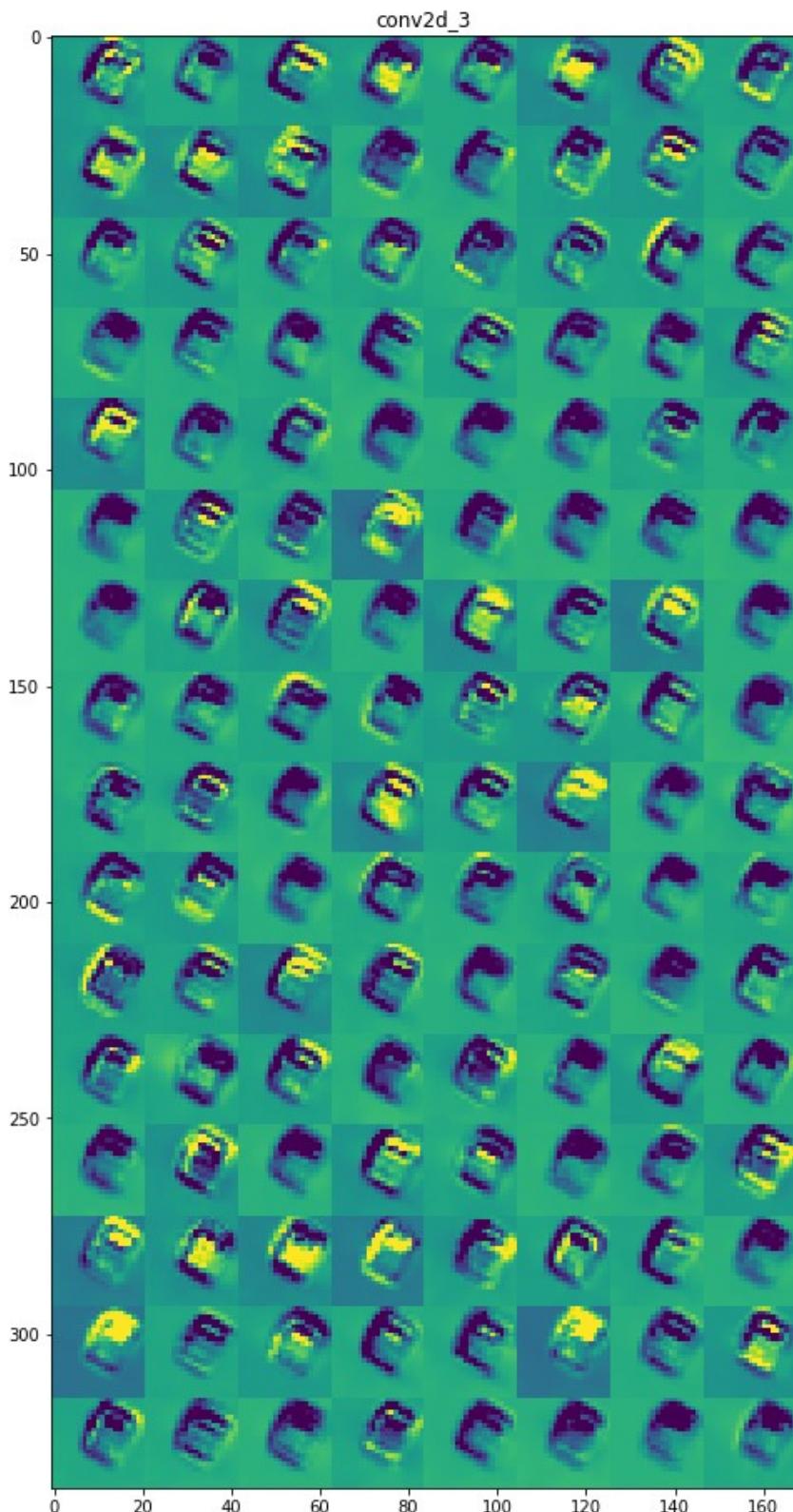


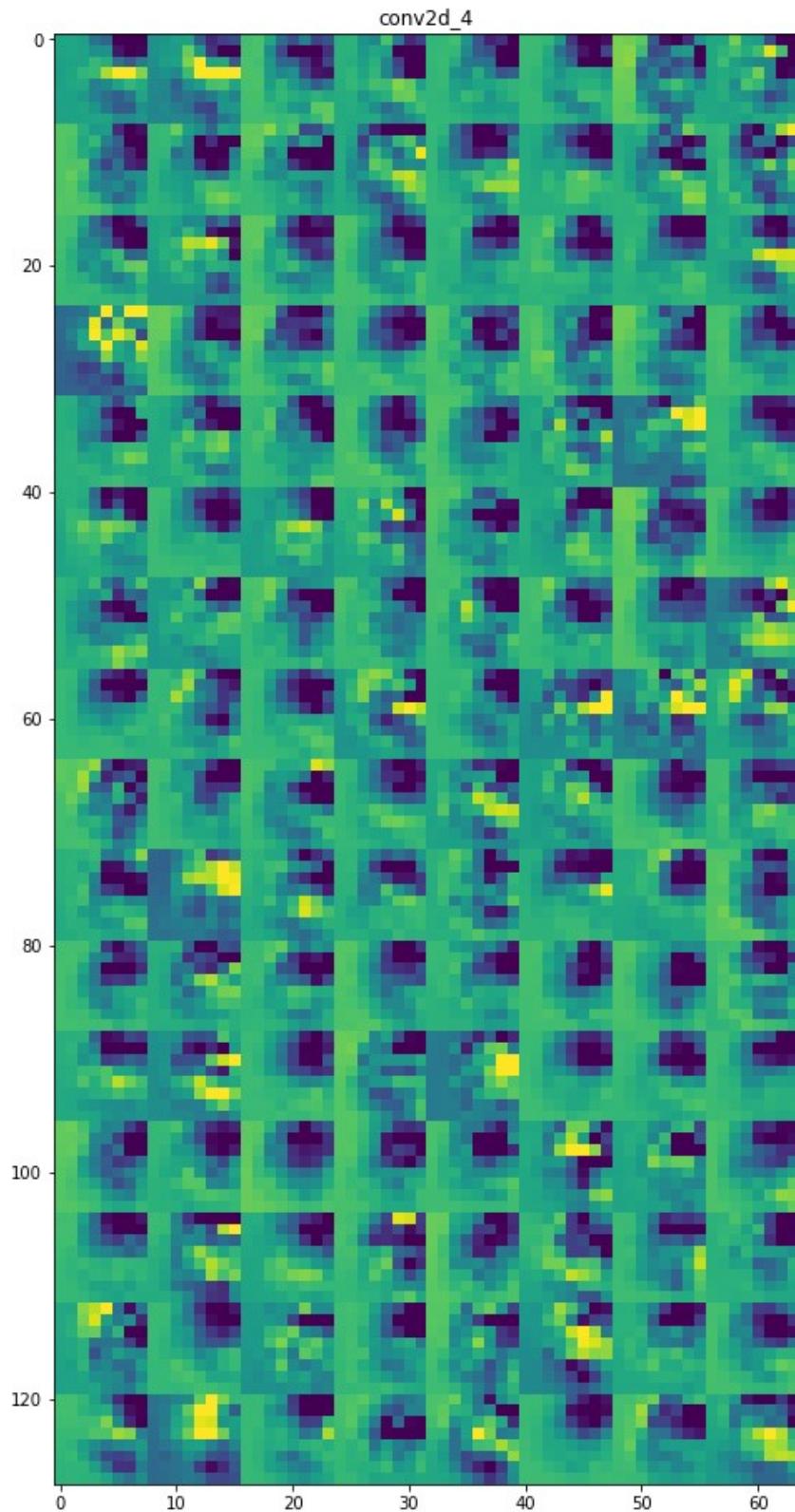


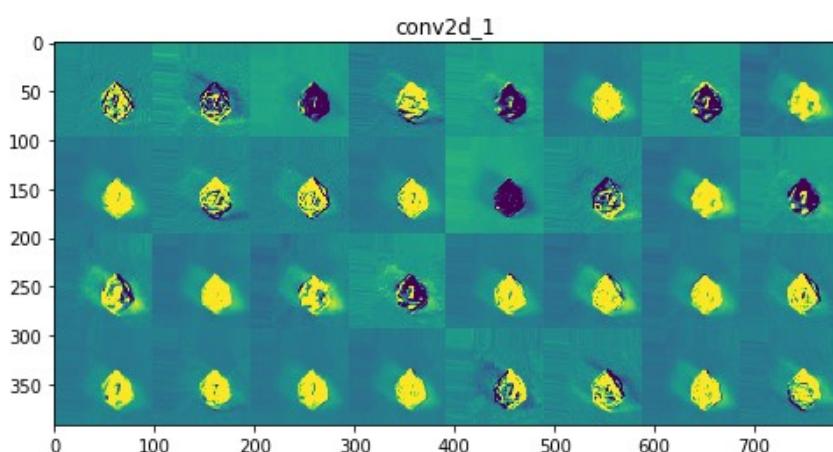
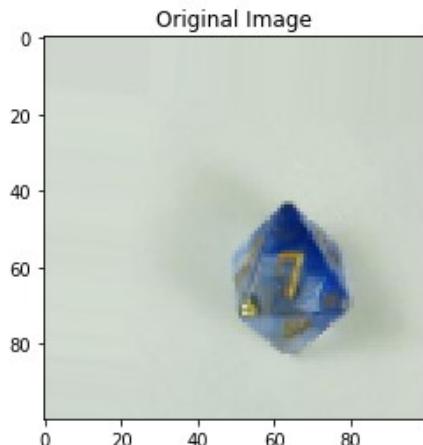


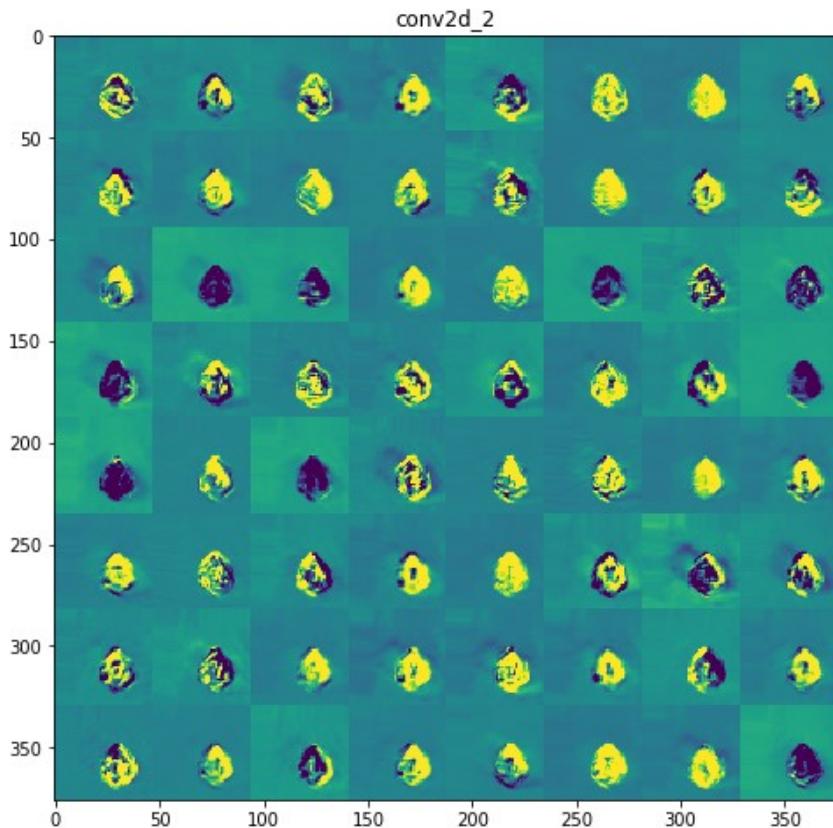


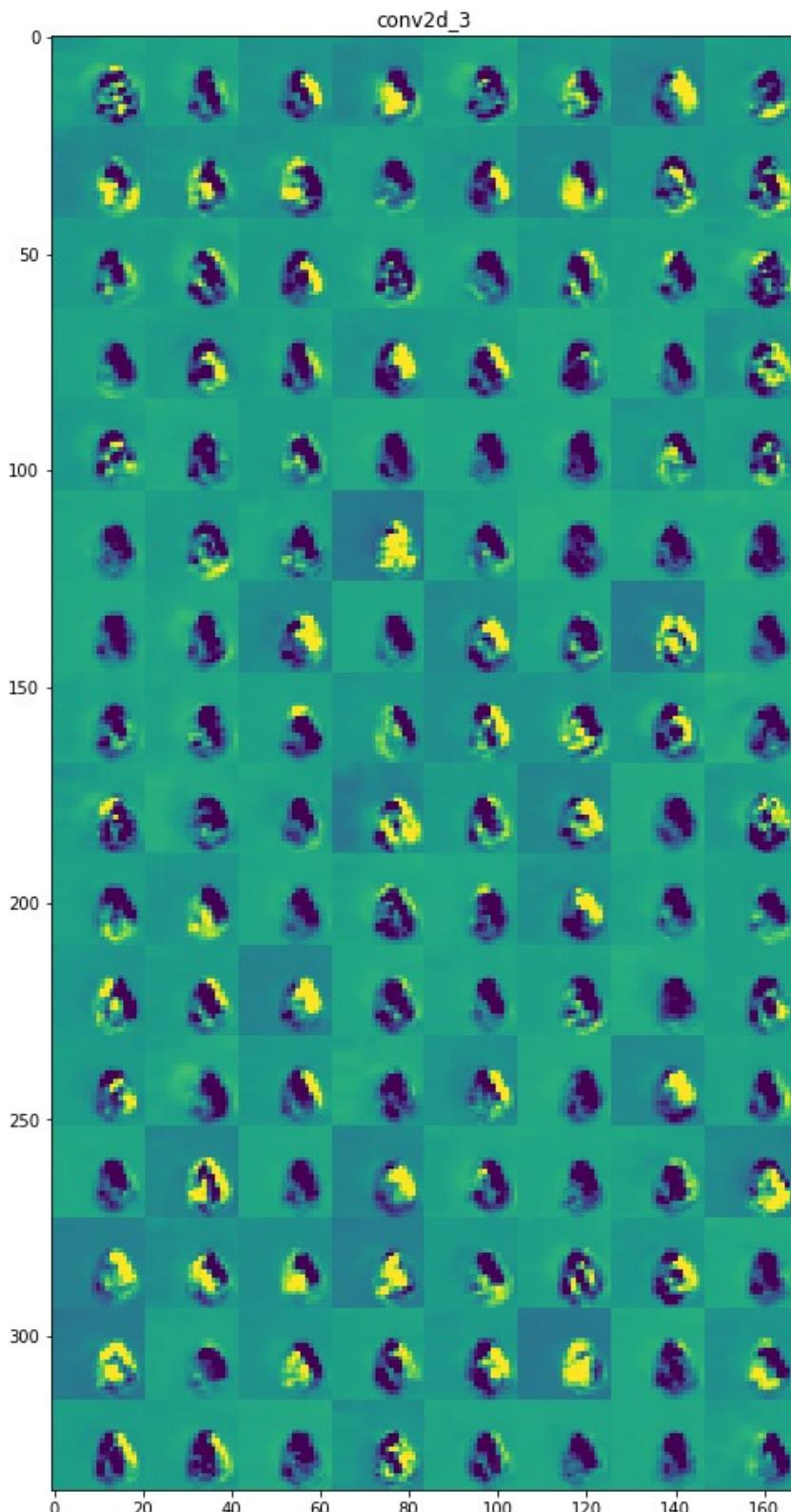


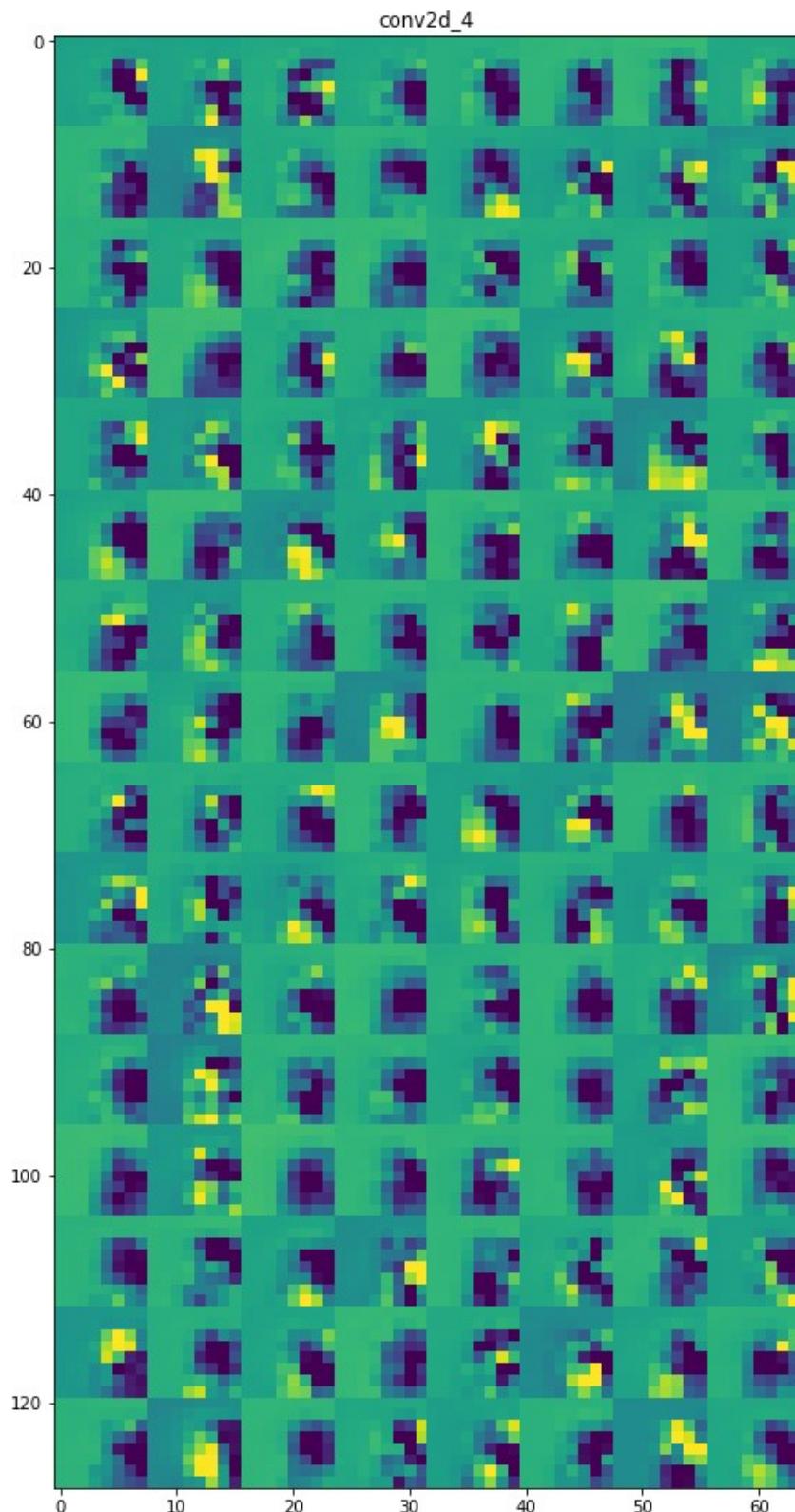


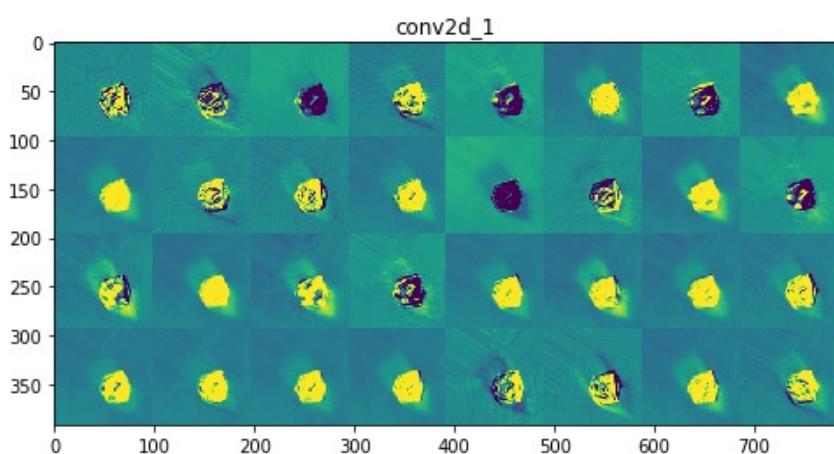
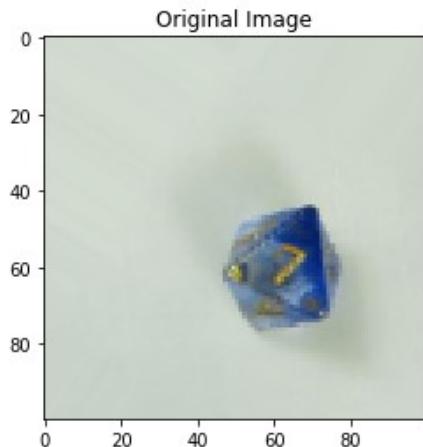


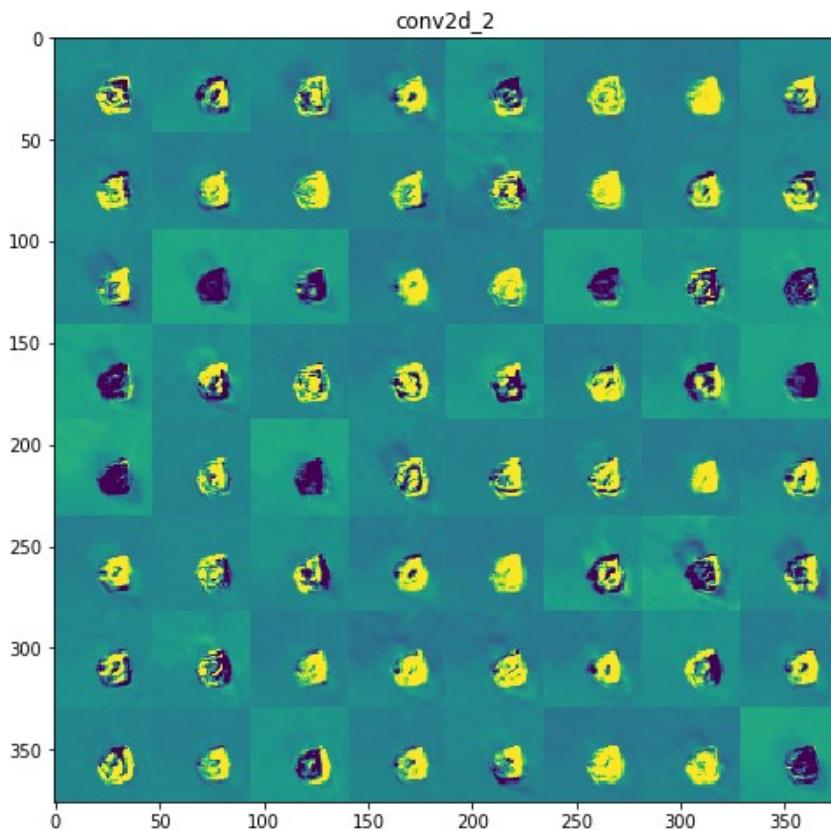


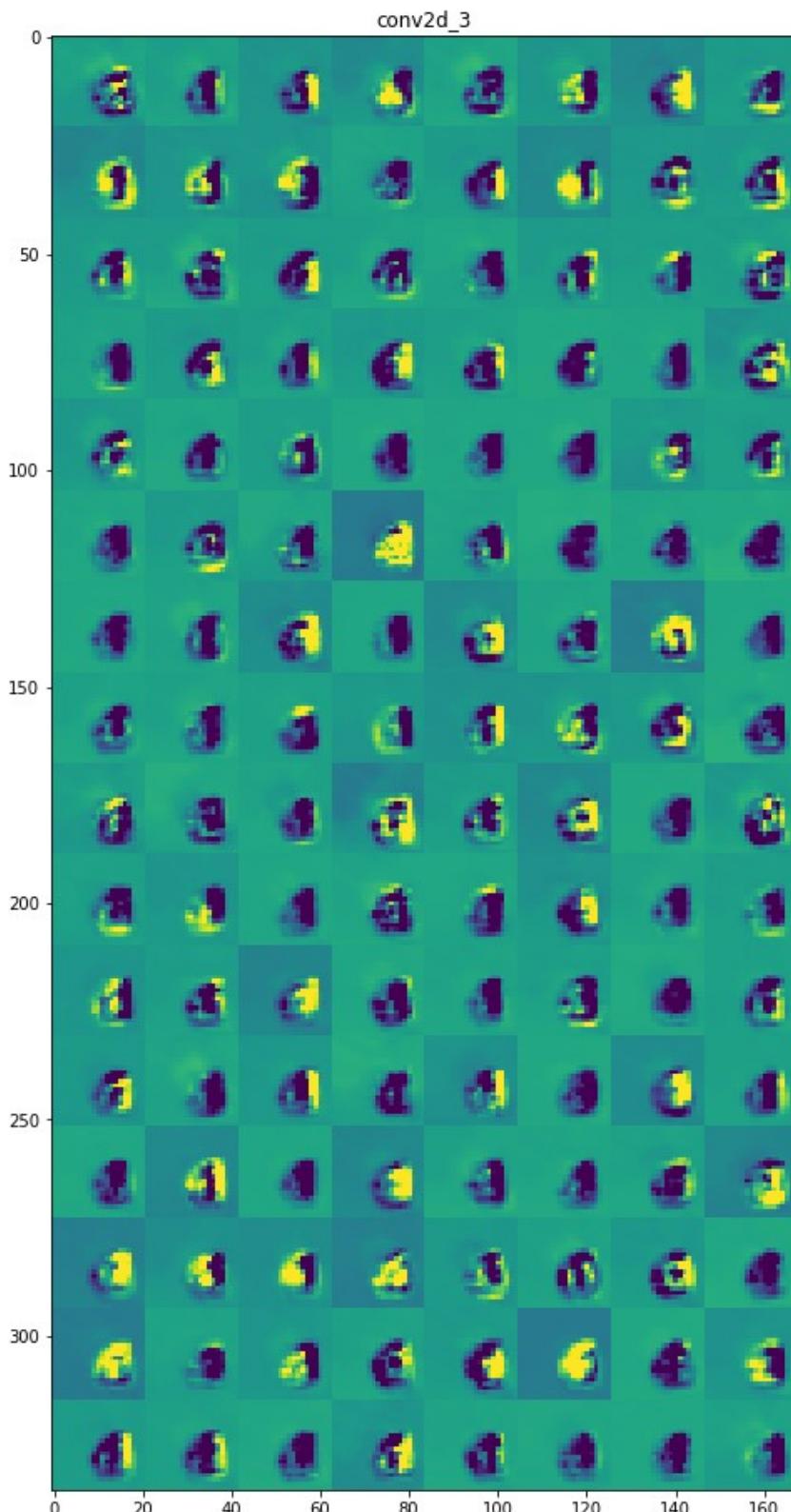


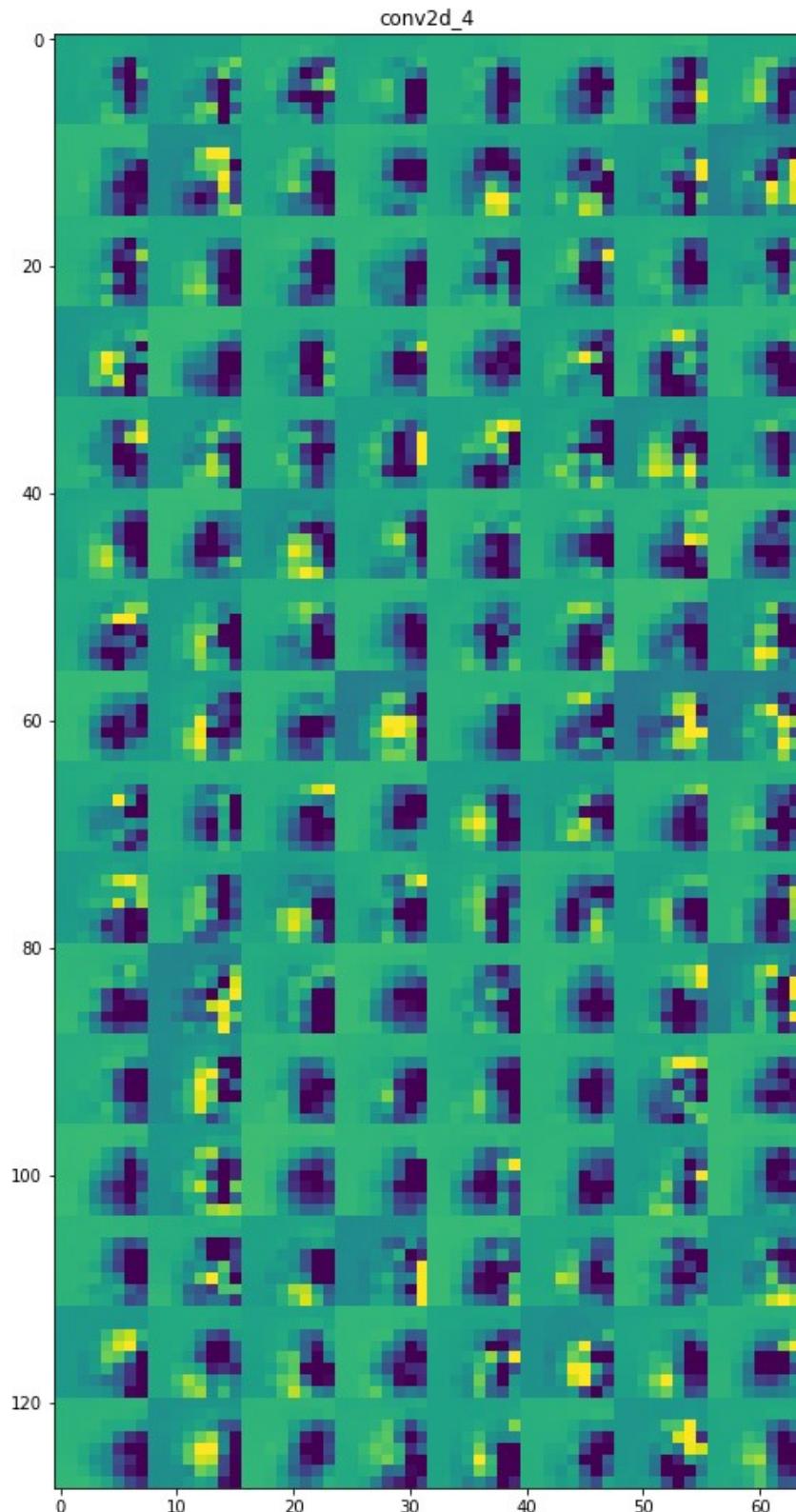


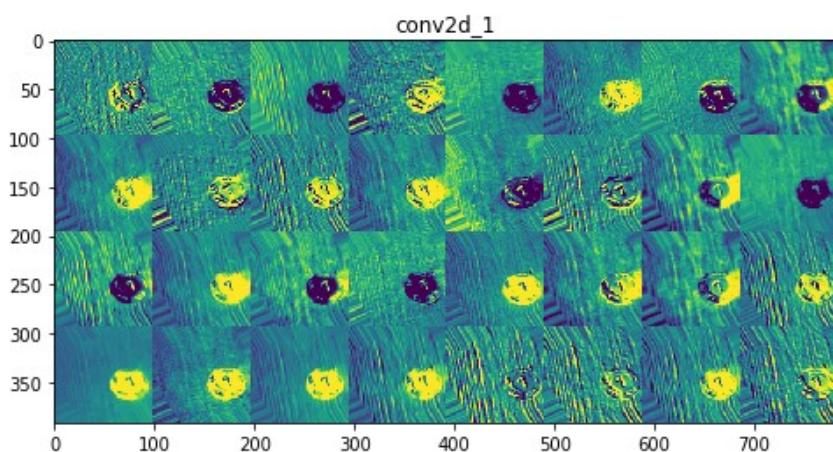
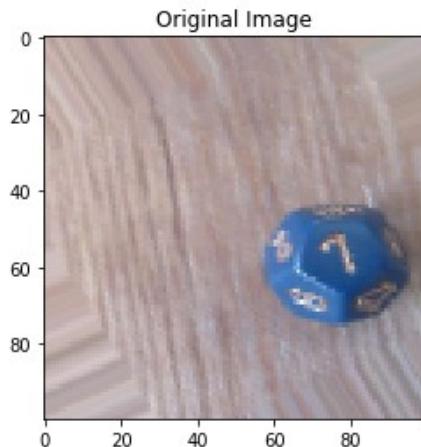


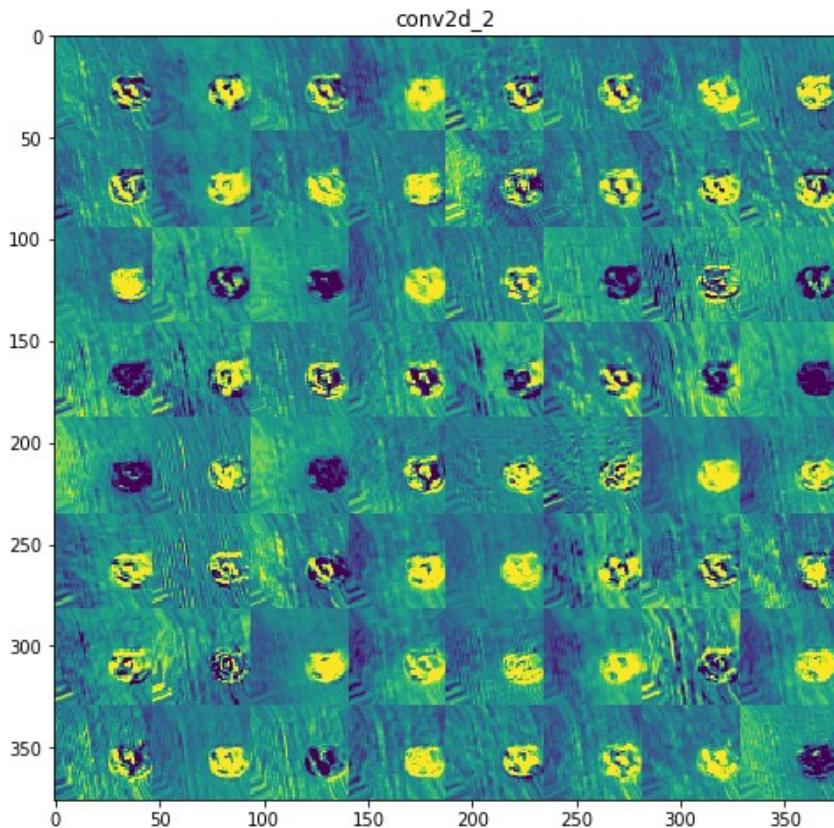


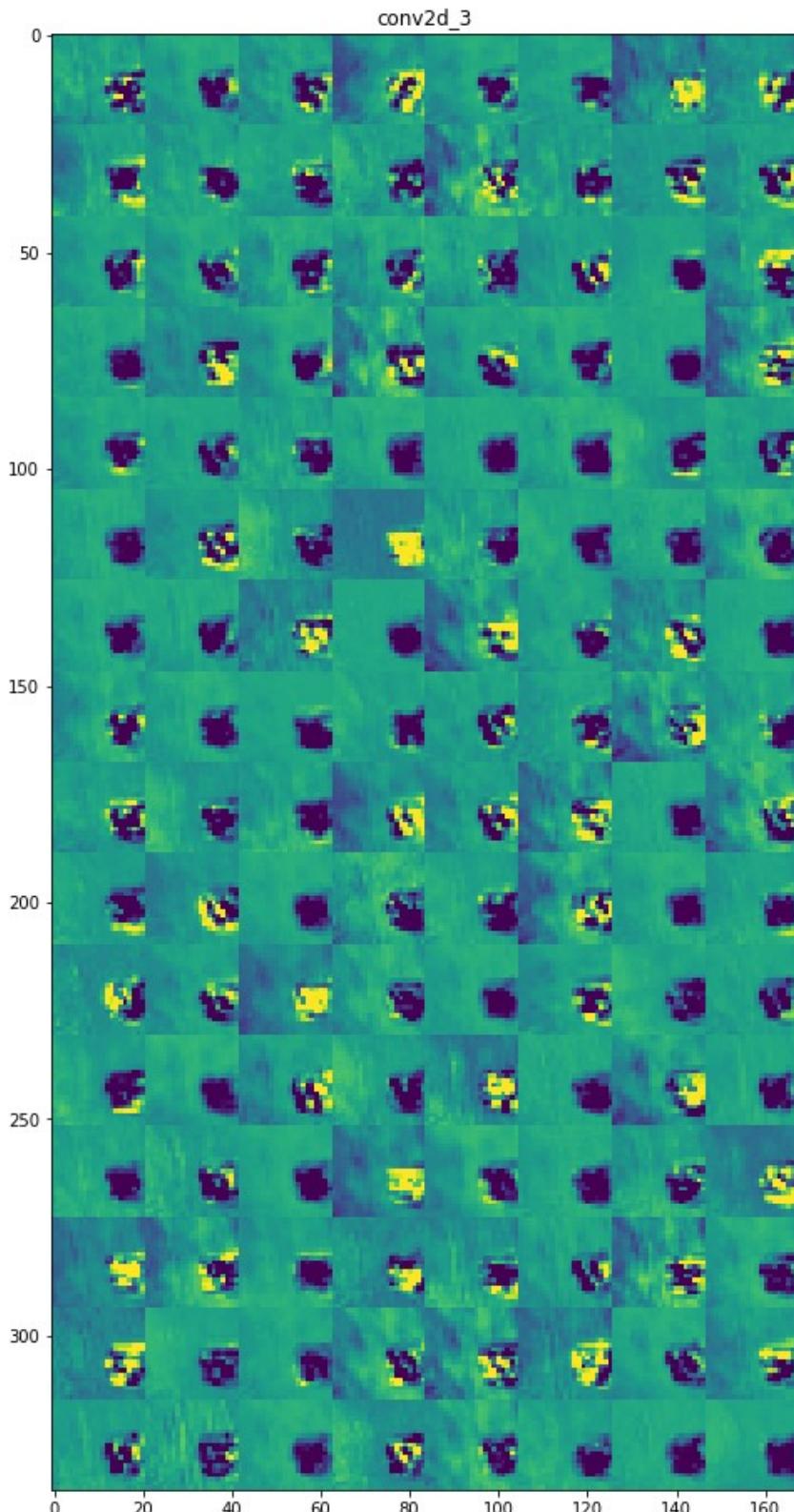


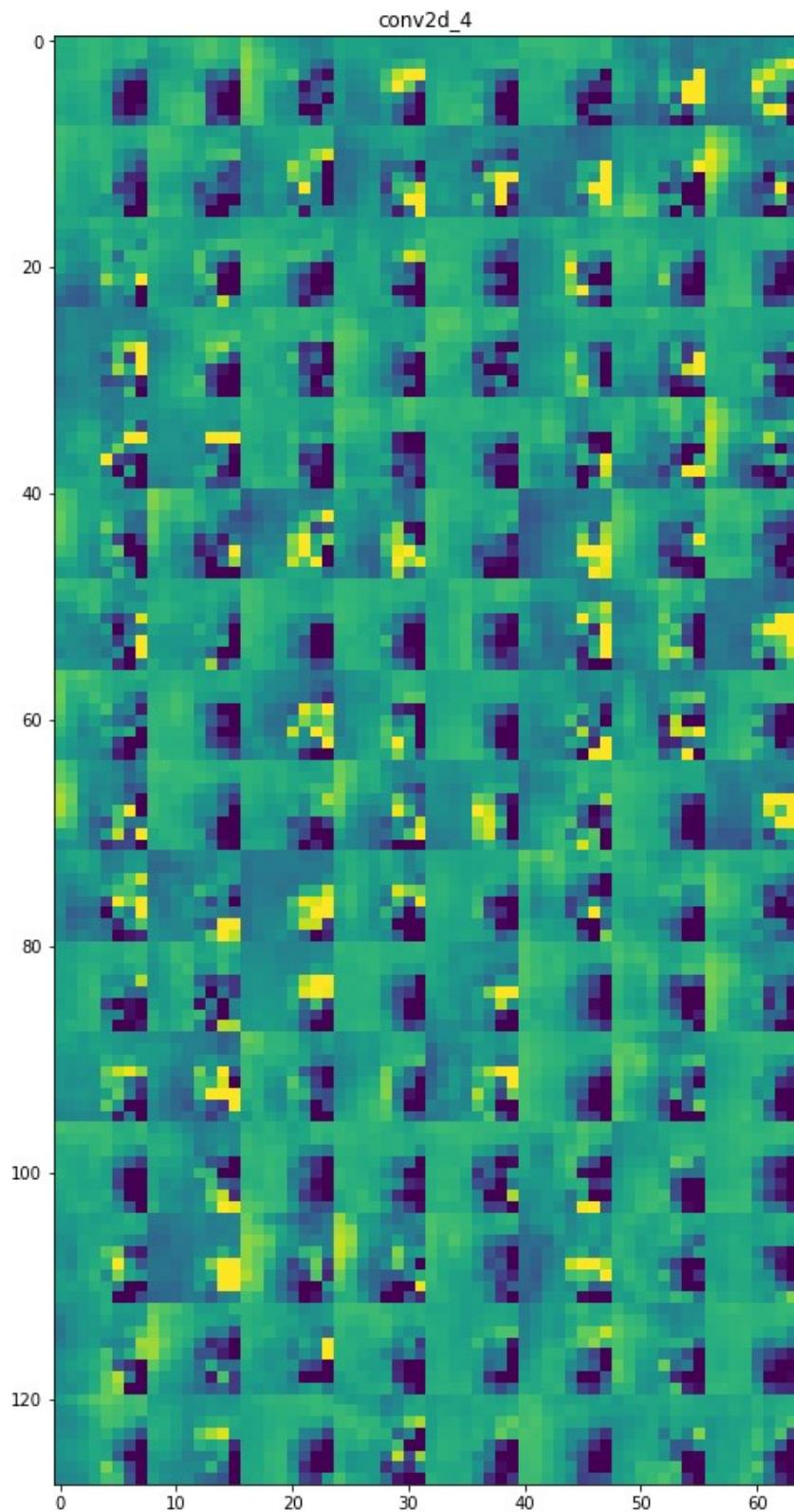


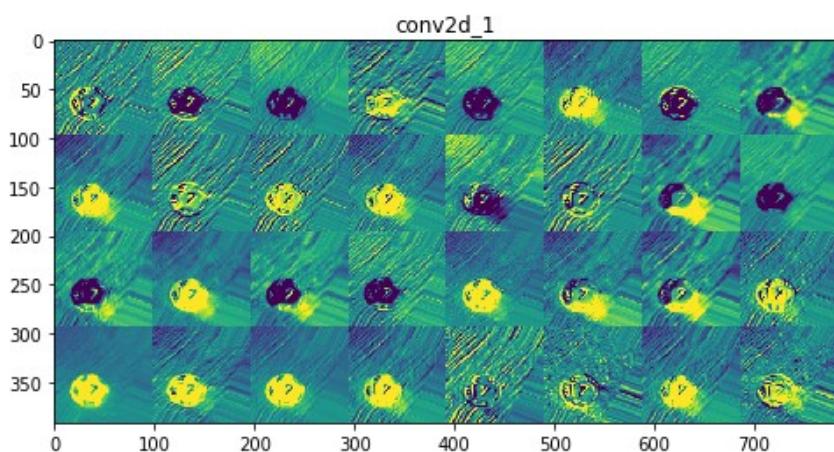
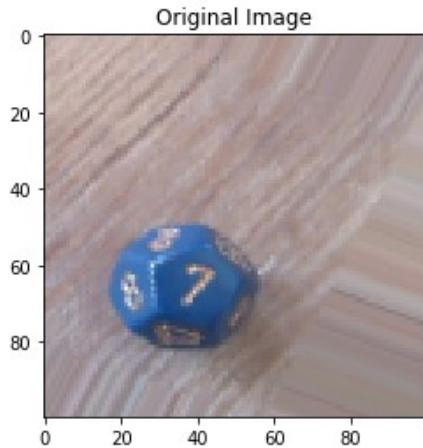


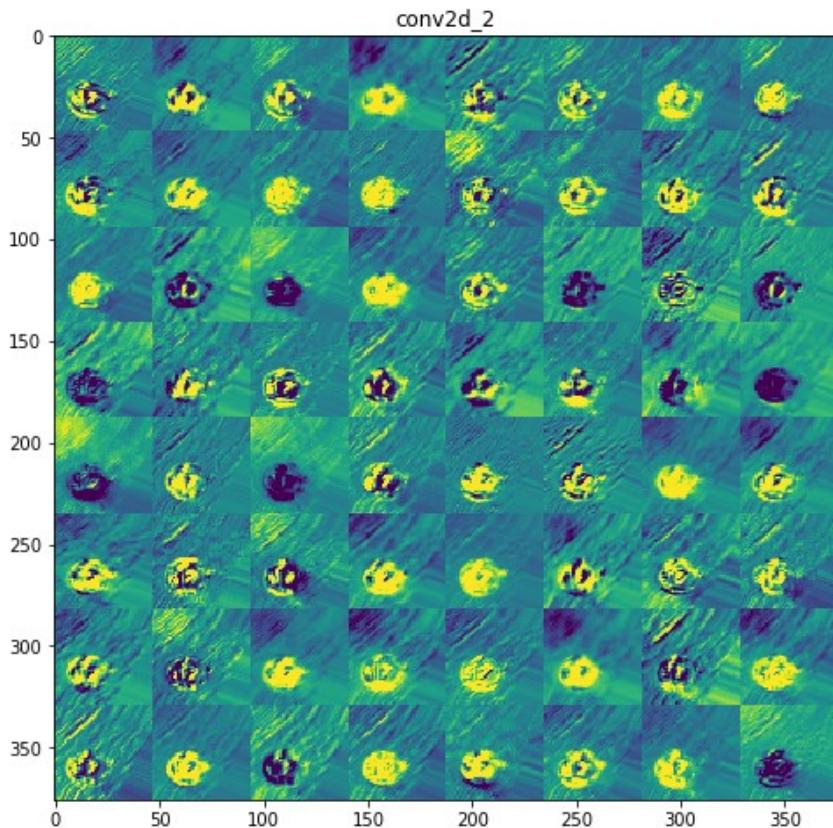


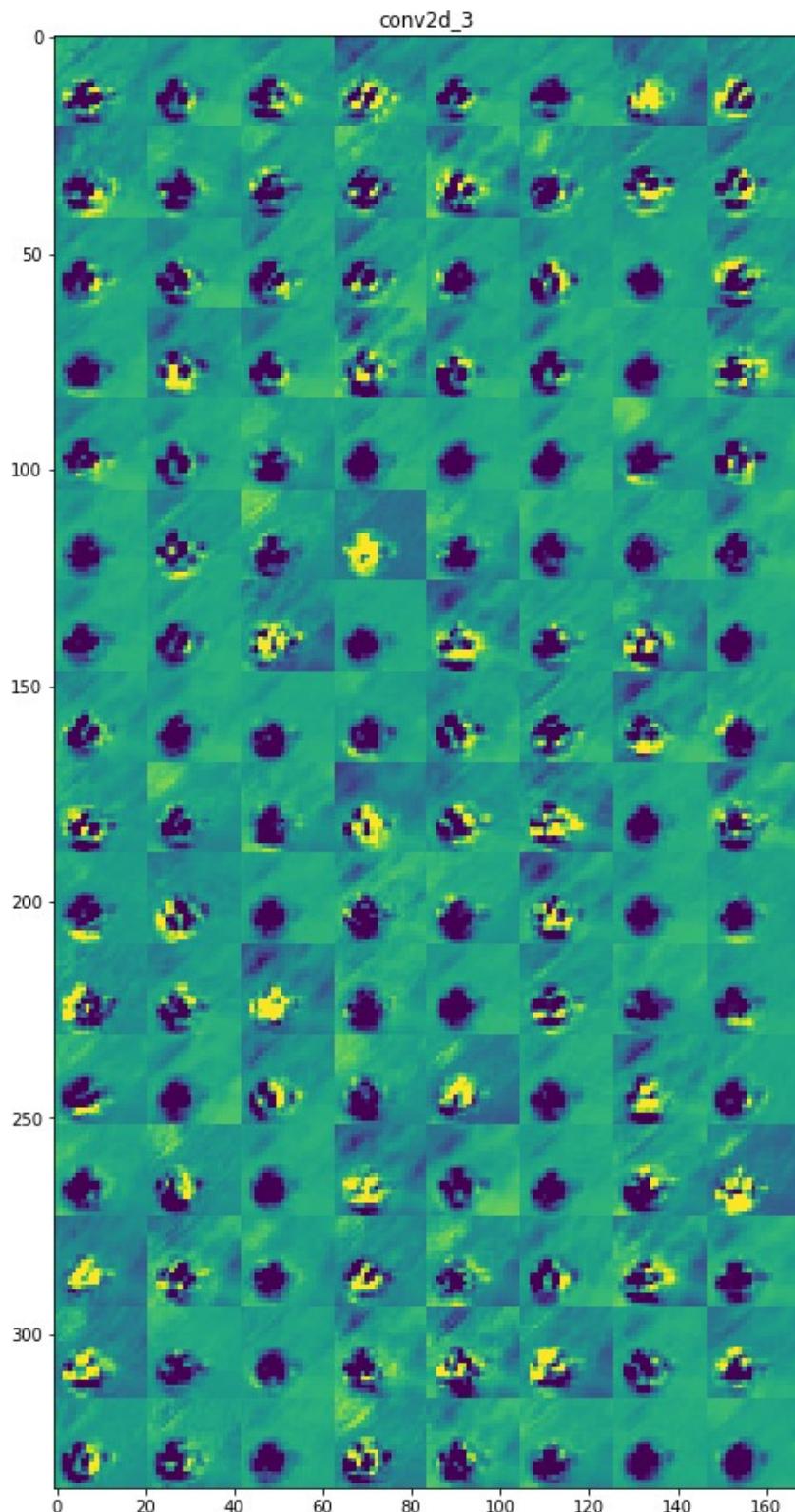


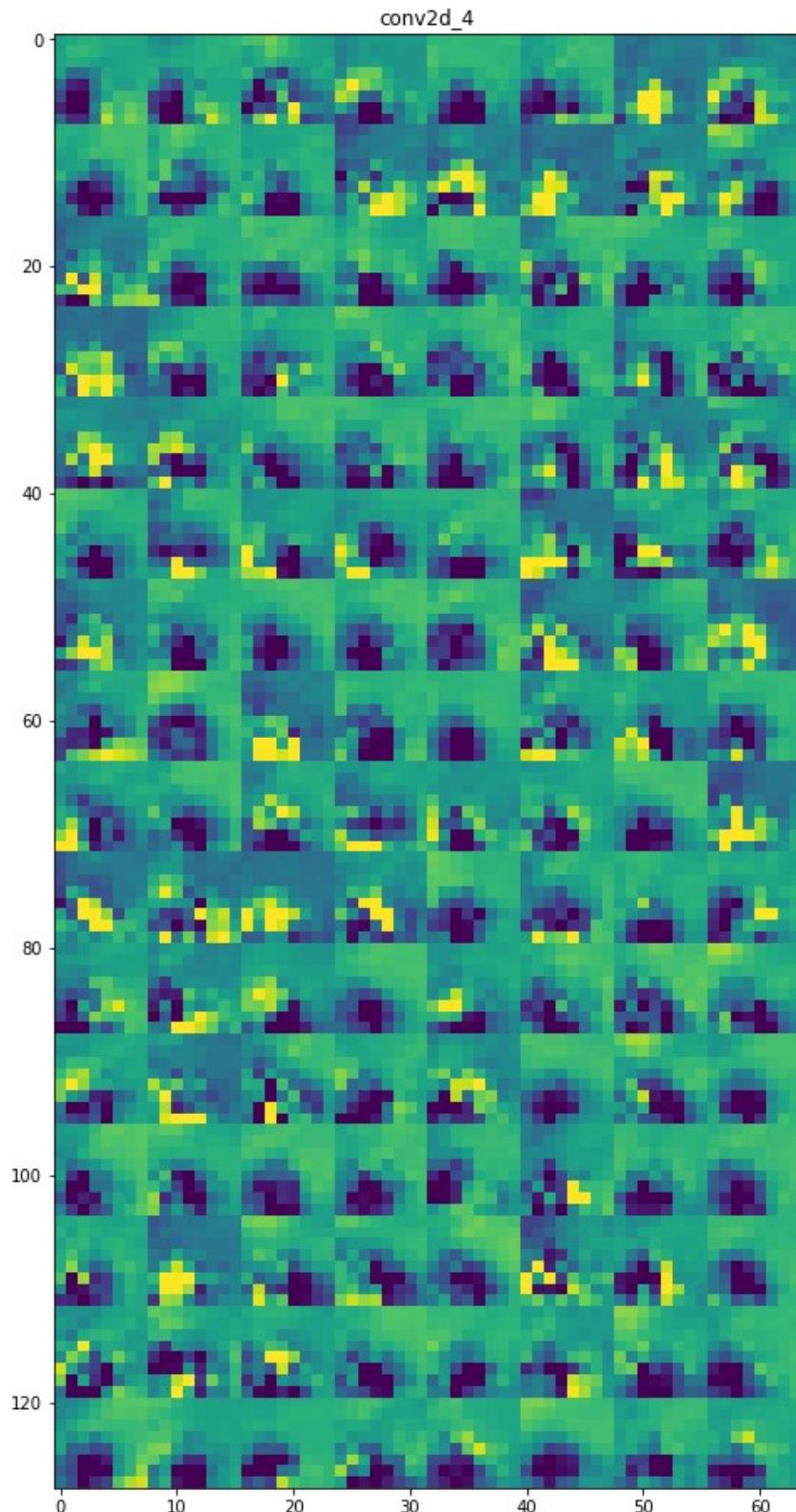


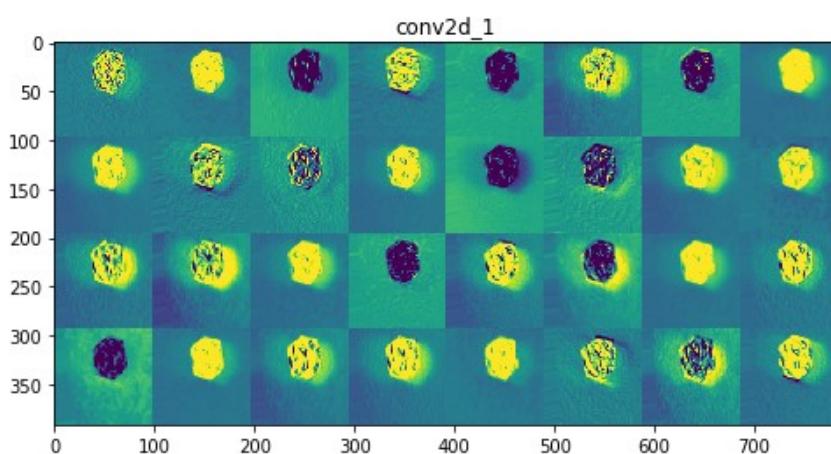
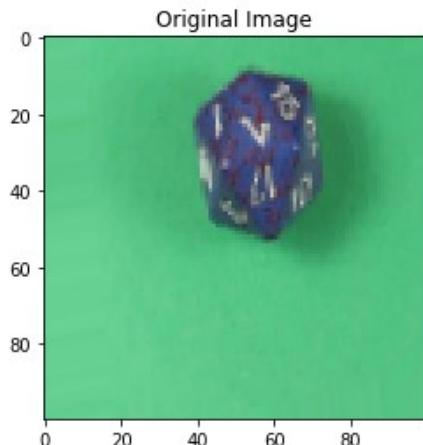


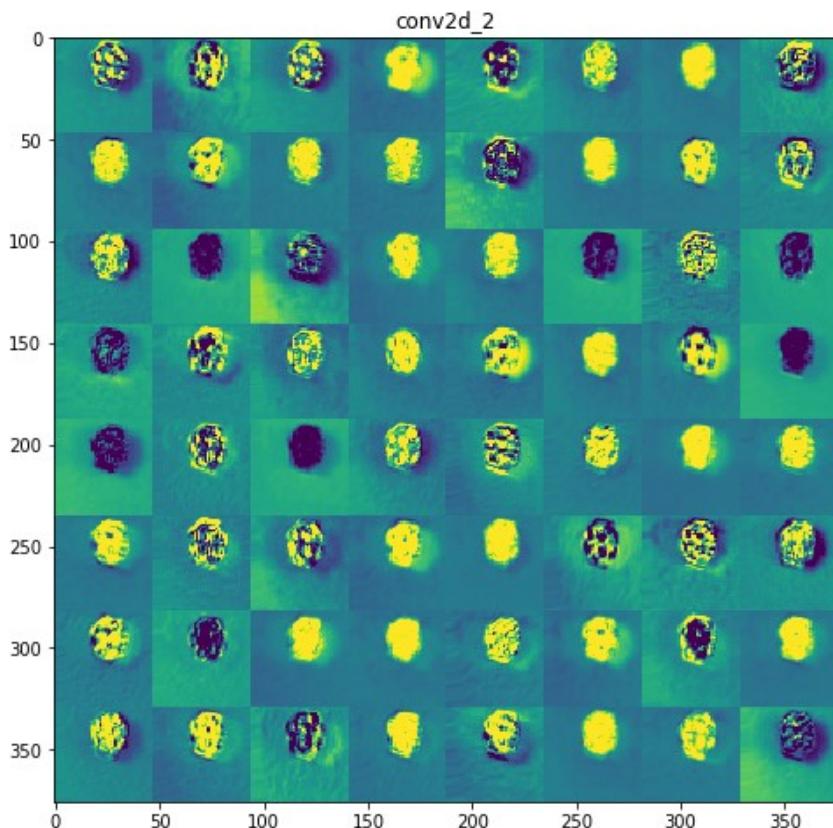


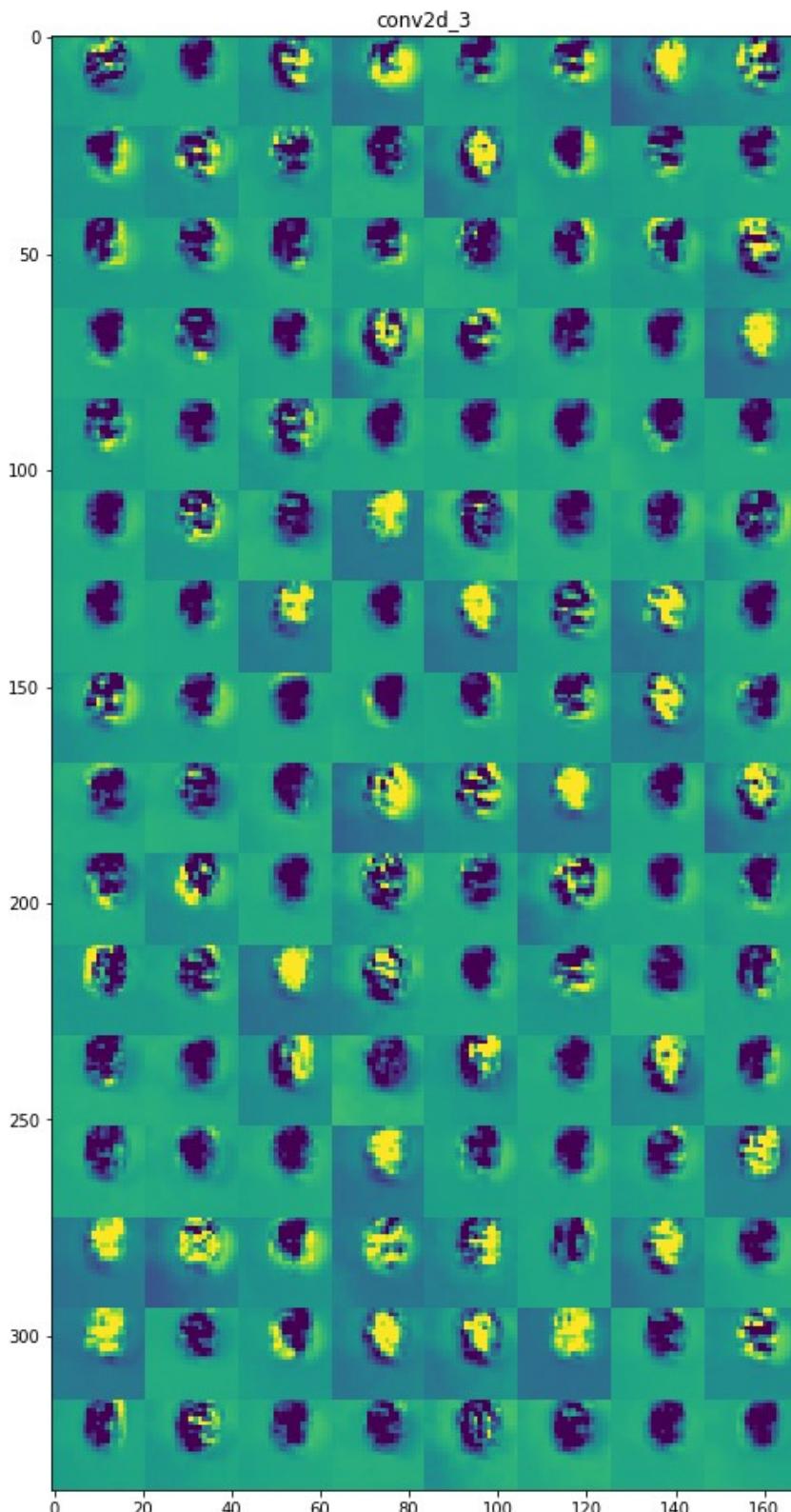


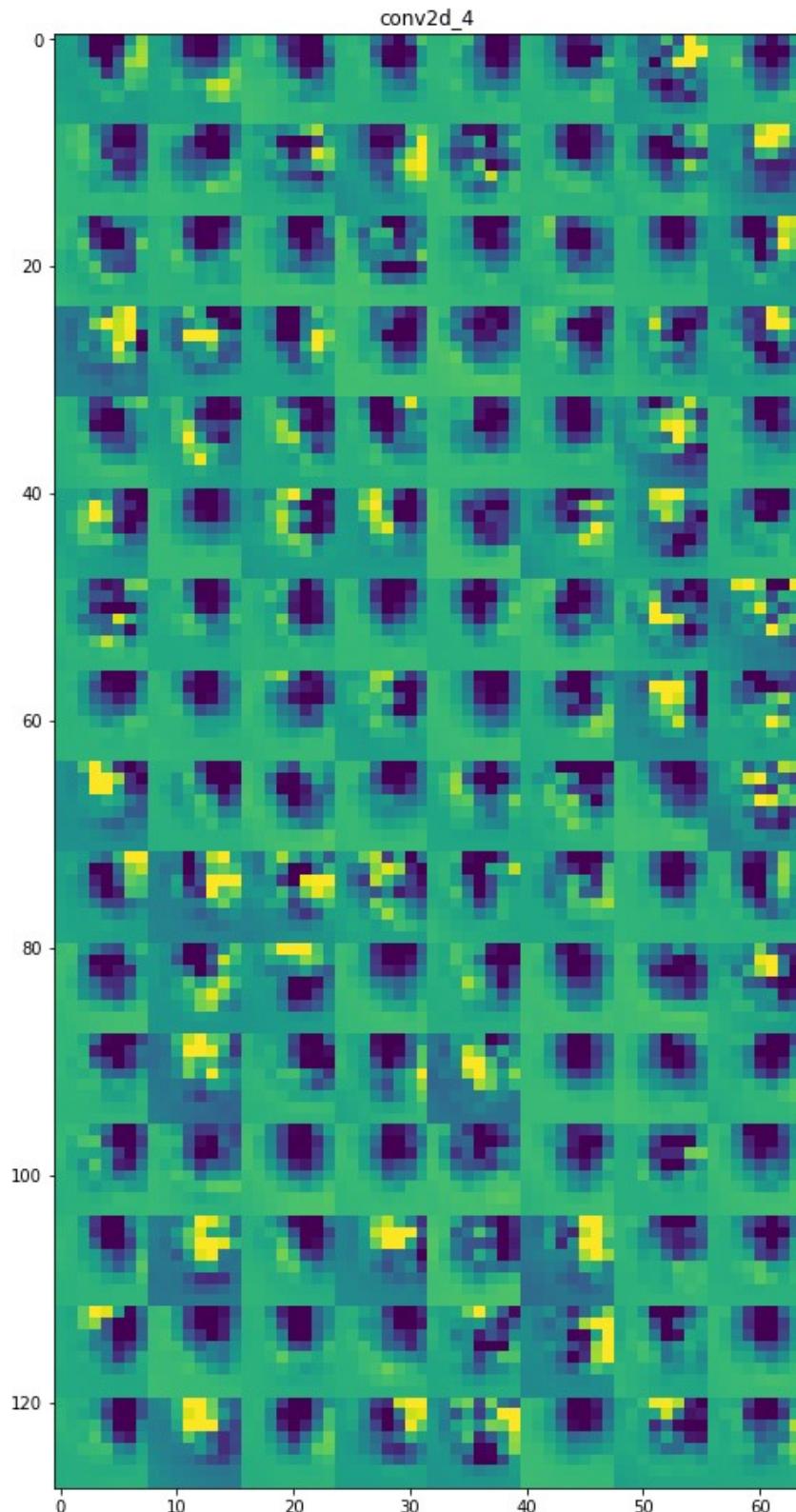


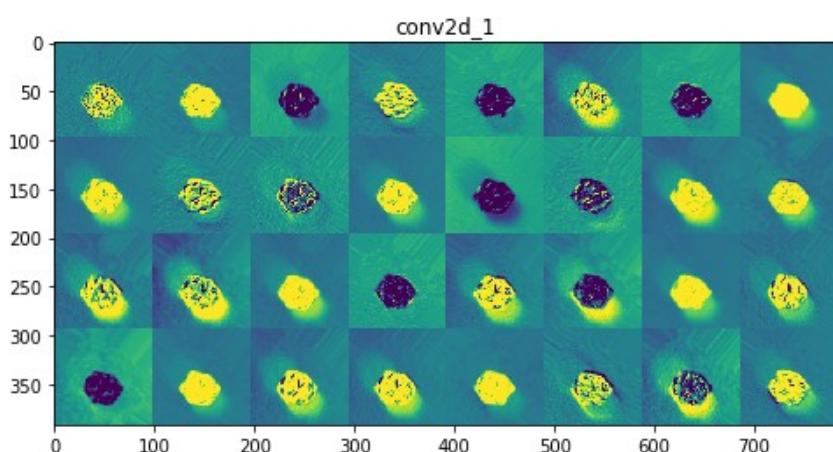
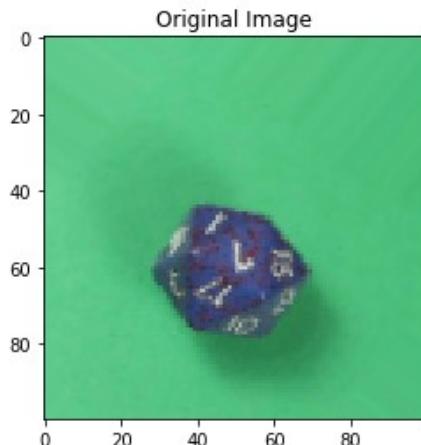


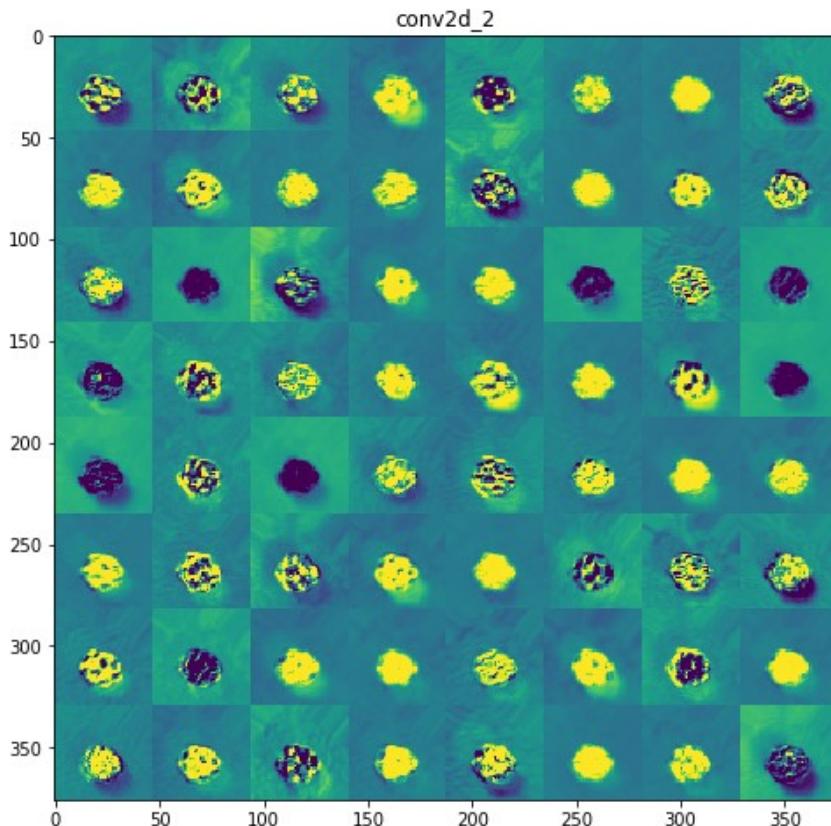


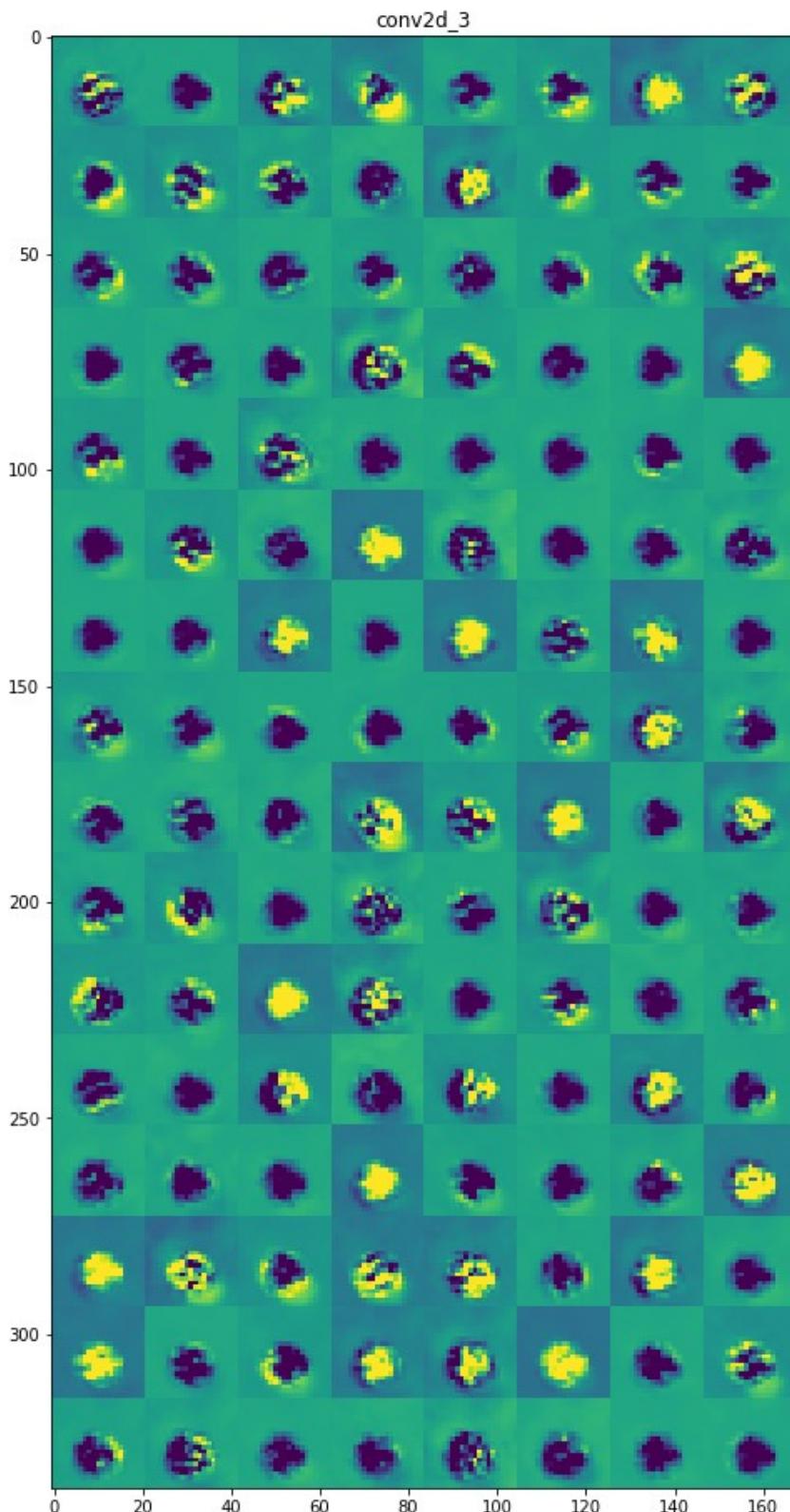


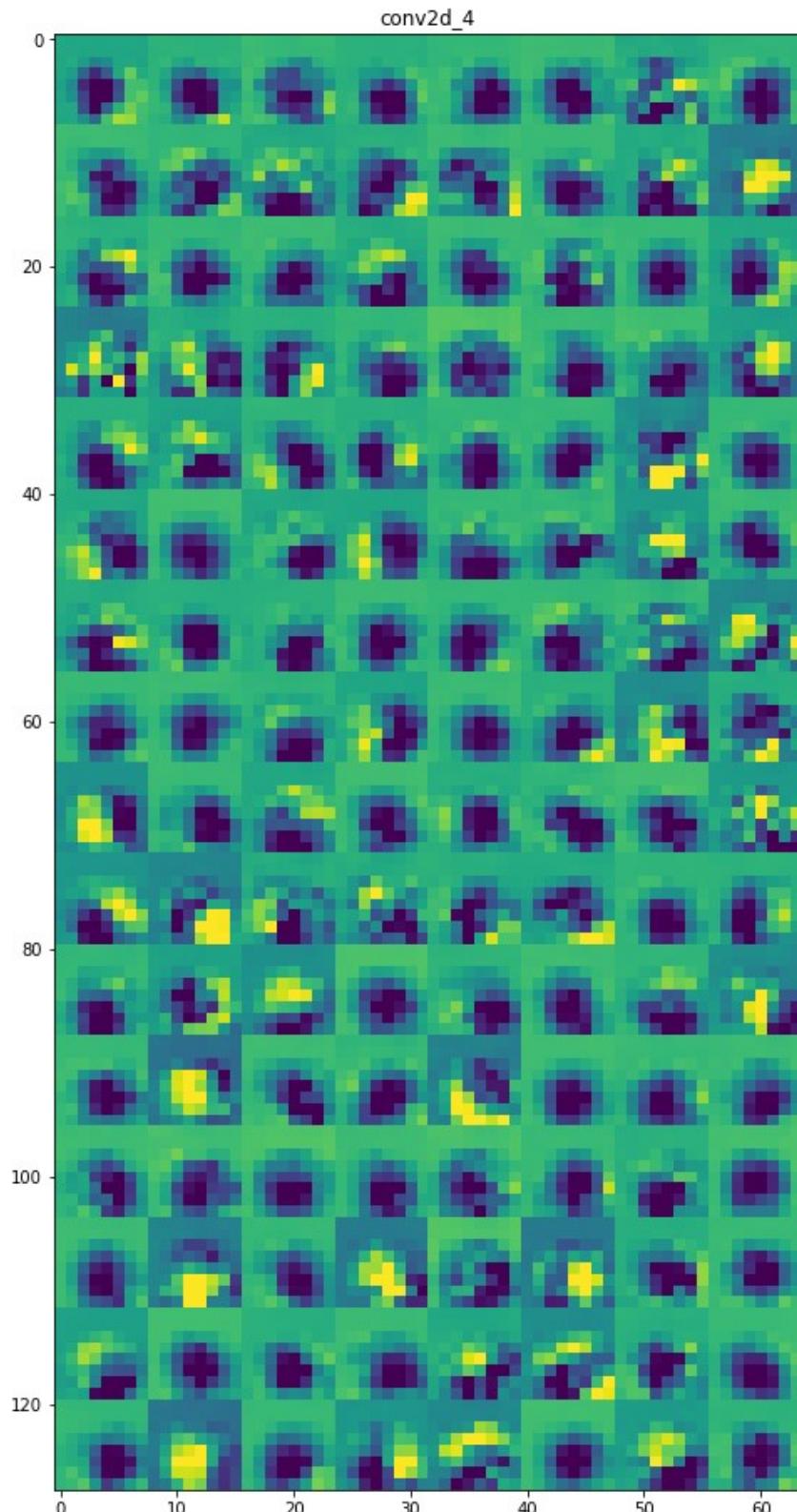












Visualizing the activation maps when the CNN makes a prediction is a good way to visualize the type of data that is being collected and how it is abstracted by later layers. For instance when we look at the first layer conv2d\_1 seems to collect some fur texture, silhouette, contours, and other such data; then conv2d\_2 collects similar data, then for other layers the data becomes more generalized and abstract compared to the first 2 layers due to the dimensionality reduction. We can also see all the filters that do not contribute much or those that have been set to 0 by the dropout function.

## Visualizing Filters

```
In [32]: def deprocess_image(x):
    """utility function to convert a float array into a valid uint8 image.

    # Arguments
    x: A numpy-array representing the generated image.

    # Returns
    A processed numpy-array, which could be used in e.g. imshow.
    """
    x -= x.mean()
    x /= (x.std() + 1e-5)
    x *= 0.1
    x += 0.5
    x = np.clip(x, 0, 1)
    x *= 255
    x = np.clip(x, 0, 255).astype('uint8')
    return x

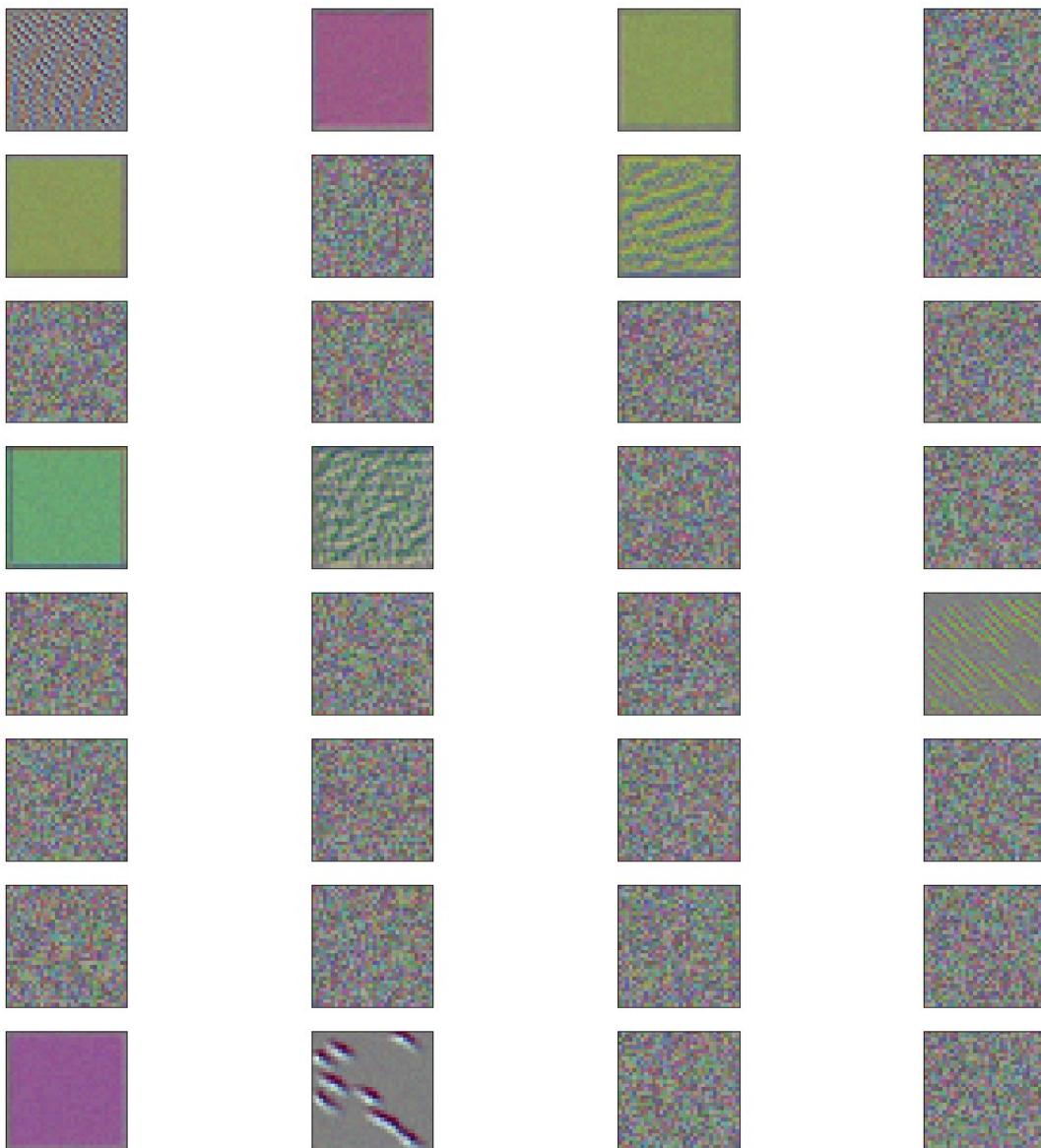
In [33]: def generate_pattern(layer_name, filter_index, size=100):
    layer_output = model.get_layer(layer_name).output
    #print(layer_output.shape)
    loss = K.mean(layer_output[:, :, :, filter_index])
    grads = K.gradients(loss, model.input)[0]
    grads /= (K.sqrt(K.mean(K.square(grads))) + 1e-5)
    iterate = K.function([model.input], [loss, grads])
    input_img_data = np.random.random((1, size, size, 3)) * 20 + 128.
    #print(input_img_data.shape)
    step = 1.
    for i in range(40):
        loss_value, grads_value = iterate([input_img_data])
        input_img_data += grads_value * step
    img = input_img_data[0]
    return deprocess_image(img)
```

```
In [34]: #model = load_model('cats_and_dogs_small_2.h5')
layer_names = [layer.name for layer in model.layers]
layer_output = model.get_layer(layer_names[0]).output
print(layer_names)
print(len(layer_names))

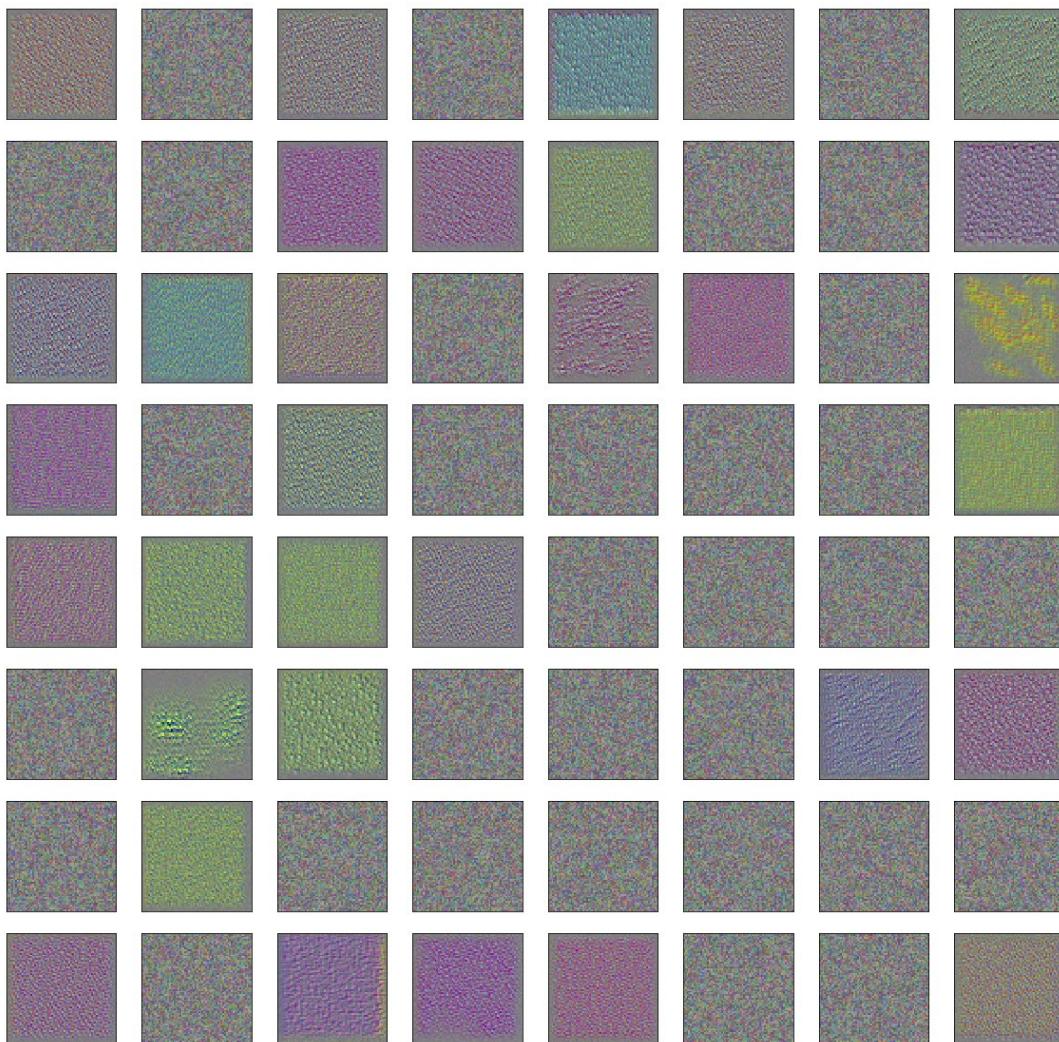
['conv2d_1', 'activation_1', 'max_pooling2d_1', 'dropout_1', 'conv2d_2', 'activation_2', 'max_poolin
g2d_2', 'dropout_2', 'conv2d_3', 'activation_3', 'max_pooling2d_3', 'dropout_3', 'conv2d_4', 'activa
tion_4', 'max_pooling2d_4', 'dropout_4', 'flatten_1', 'dense_1', 'activation_5', 'batch_normalizatio
n_1', 'dropout_5', 'dense_2', 'activation_6']
23
```

```
In [35]: # plot the filters for convolutional layers utilizing gradient decomposition
sizes = [32,64,128,128]
num_rows_and_columns = [(8,4),(8,8),(16,8),(16,8),(16,8),(16,8)]
index = 1
for layer_name, size, c_and_n in zip(layer_names[1:14:4], sizes, num_rows_and_columns):
    print(model.get_layer(layer_name).output)
    print(size)
    print(c_and_n)
    plt.figure(figsize=(20,20), facecolor='w')
    plt.title(layer_name)
    for i in range(size):
        filter_img = generate_pattern(layer_name, i, size=size)
        plt.subplot(c_and_n[0],c_and_n[1],index)
        plt.imshow(filter_img)
        plt.xticks([])
        plt.yticks([])
        index = index + 1
    index = 1
plt.show()
```

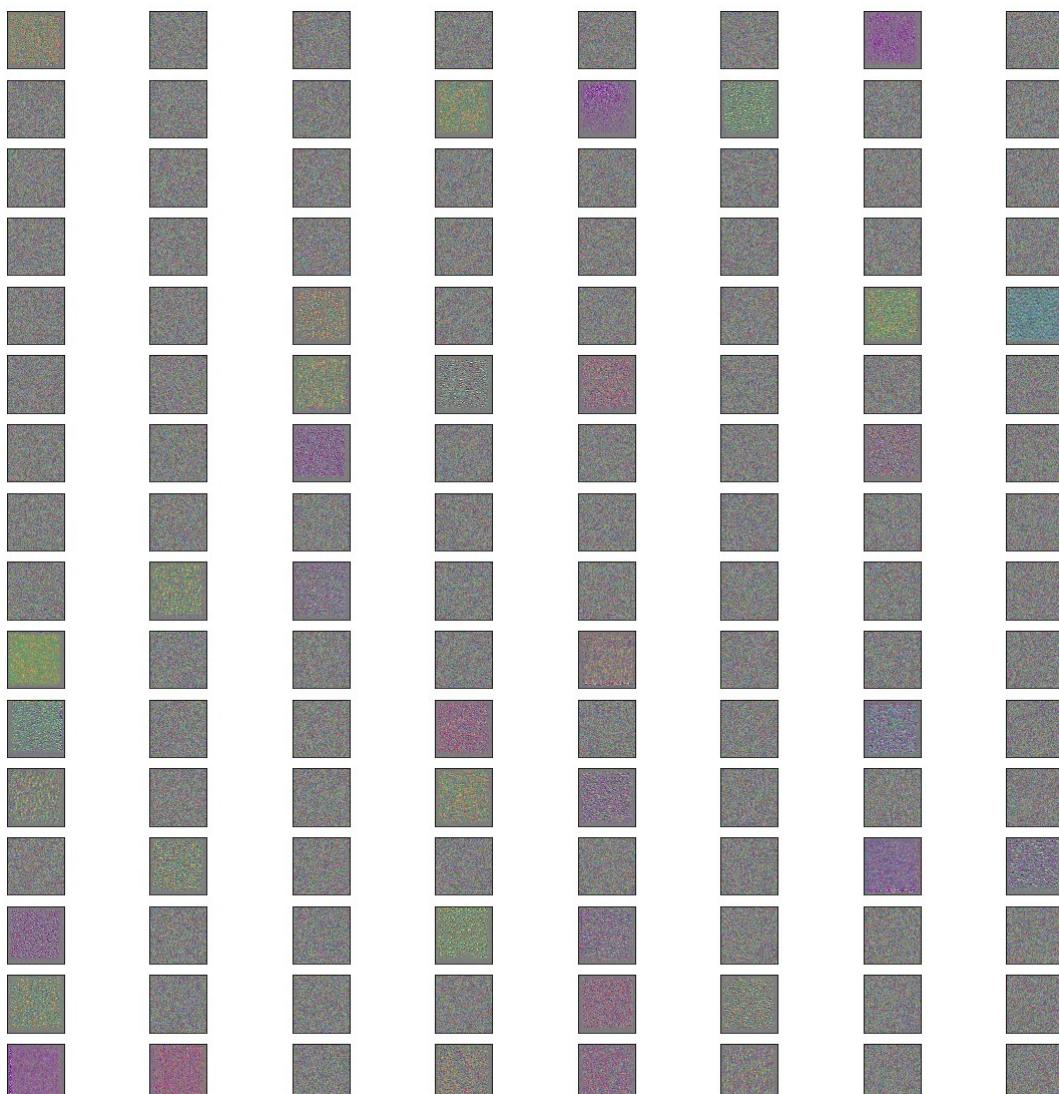
```
Tensor("activation_1/Relu:0", shape=(None, 98, 98, 32), dtype=float32)
32
(8, 4)
```



```
Tensor("activation_2/Relu:0", shape=(None, 47, 47, 64), dtype=float32)
64
(8, 8)
```



```
Tensor("activation_3/Relu:0", shape=(None, 21, 21, 128), dtype=float32)
128
(16, 8)
```



```
Tensor("activation_4/Relu:0", shape=(None, 8, 8, 128), dtype=float32)
128
(16, 8)
```



In [ ]: