pool_visualization

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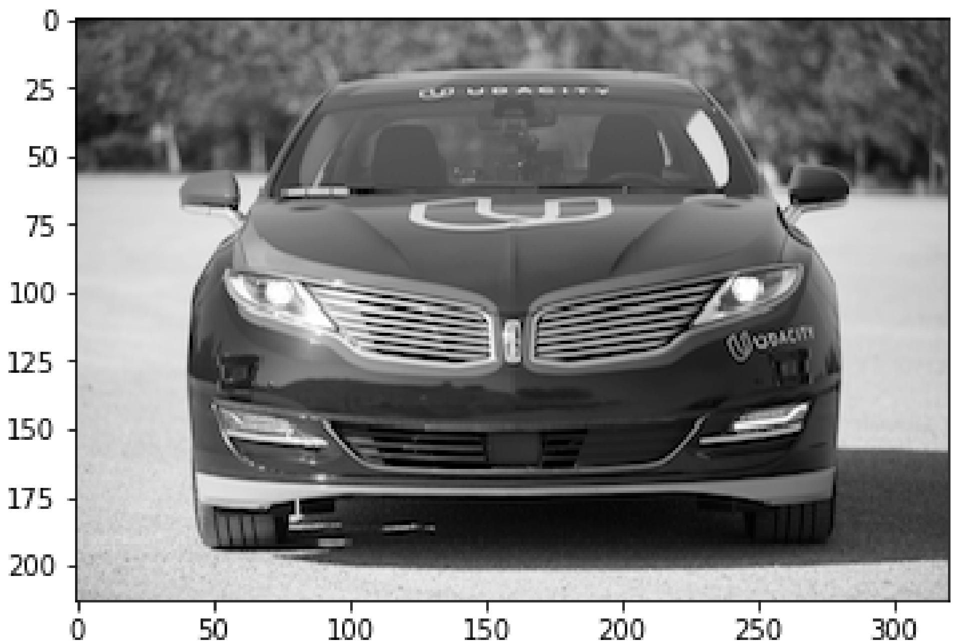
0.1 # Pooling Layer

In this notebook, we add and visualize the output of a maxpooling layer in a CNN.

0.1.1 Import the image

```
In [1]: import cv2
        import matplotlib.pyplot as plt
        %matplotlib inline

        # TODO: Feel free to try out your own images here by changing img_path
        # to a file path to another image on your computer!
        img_path = 'images/udacity_sdc.png'

        # load color image
        bgr_img = cv2.imread(img_path)
        # convert to grayscale
        gray_img = cv2.cvtColor(bgr_img, cv2.COLOR_BGR2GRAY)

        # normalize, rescale entries to lie in [0,1]
        gray_img = gray_img.astype("float32")/255

        # plot image
        plt.imshow(gray_img, cmap='gray')
        plt.show()
```



0.1.2 Define and visualize the filters

```
In [2]: import numpy as np

        ## TODO: Feel free to modify the numbers here, to try out another filter!
        filter_vals = np.array([[-1, -1, 1, 1], [-1, -1, 1, 1], [-1, -1, 1, 1], [-1, -1, 1, 1]])

        print('Filter shape: ', filter_vals.shape)
```

```
Filter shape:  (4, 4)
```

```
In [3]: # Defining four different filters,
        # all of which are linear combinations of the `filter_vals` defined above

        # define four filters
        filter_1 = filter_vals
        filter_2 = -filter_1
        filter_3 = filter_1.T
        filter_4 = -filter_3
        filters = np.array([filter_1, filter_2, filter_3, filter_4])

        # For an example, print out the values of filter 1
        print('Filter 1: \n', filter_1)
```

```
Filter 1:
 [[-1 -1  1  1]
```

```
 [-1 -1  1  1]
 [-1 -1  1  1]
 [-1 -1  1  1]]
```

0.1.3 Define convolutional and pooling layers

Initialize a convolutional layer so that it contains all your created filters. Then add a maxpooling layer, documented here, with a kernel size of (4x4) so you can really see that the image resolution has been reduced after this step!

```
In [4]: import torch
        import torch.nn as nn
        import torch.nn.functional as F


        # define a neural network with a convolutional layer with four filters
        # AND a pooling layer of size (4, 4)
        class Net(nn.Module):

            def __init__(self, weight):
                super(Net, self).__init__()
                # initializes the weights of the convolutional layer to be the weights of the 4
                k_height, k_width = weight.shape[2:]
                # assumes there are 4 grayscale filters
                self.conv = nn.Conv2d(1, 4, kernel_size=(k_height, k_width), bias=False)
                self.conv.weight = torch.nn.Parameter(weight)
                # define a pooling layer
                self.pool = nn.MaxPool2d(4, 4)

            def forward(self, x):
                # calculates the output of a convolutional layer
                # pre- and post-activation
                conv_x = self.conv(x)
                activated_x = F.relu(conv_x)

                # applies pooling layer
                pooled_x = self.pool(activated_x)

                # returns all layers
                return conv_x, activated_x, pooled_x

        # instantiate the model and set the weights
        weight = torch.from_numpy(filters).unsqueeze(1).type(torch.FloatTensor)
        model = Net(weight)

        # print out the layer in the network
        print(model)
```

```
Net(
  (conv): Conv2d(1, 4, kernel_size=(4, 4), stride=(1, 1), bias=False)
  (pool): MaxPool2d(kernel_size=4, stride=4, padding=0, dilation=1, ceil_mode=False)
)
```

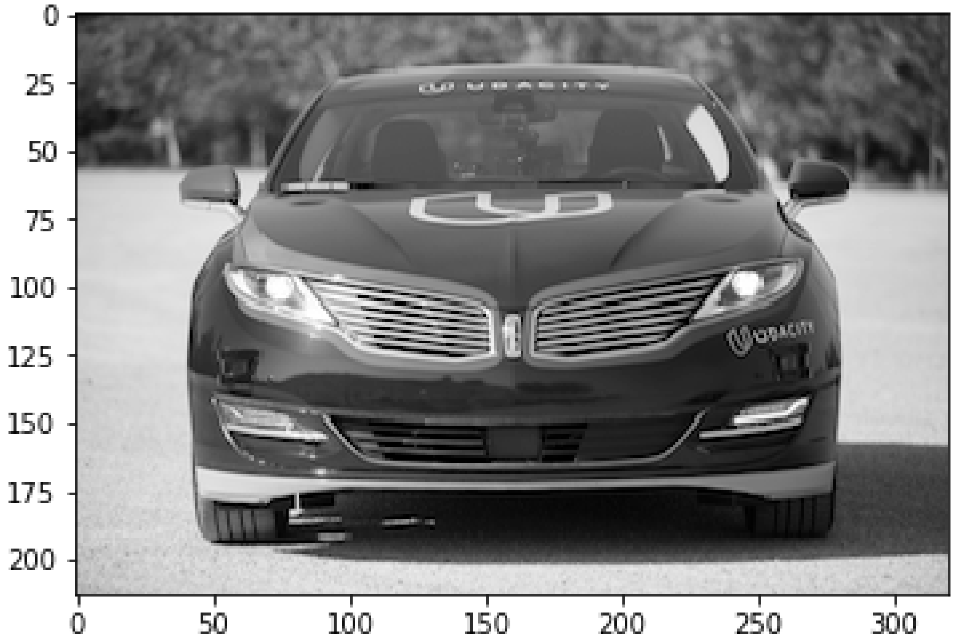
0.1.4 Visualize the output of each filter

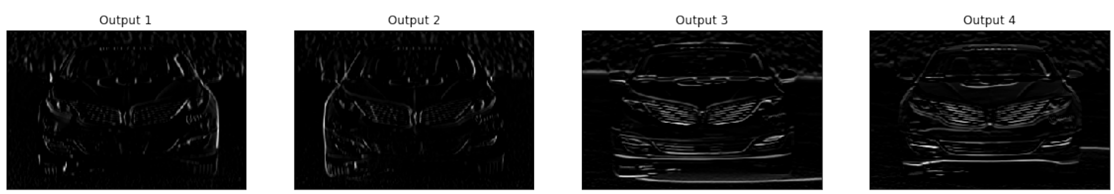
First, we'll define a helper function, `viz_layer` that takes in a specific layer and number of filters (optional argument), and displays the output of that layer once an image has been passed through.

In [5]:
```
# helper function for visualizing the output of a given layer
# default number of filters is 4
def viz_layer(layer, n_filters= 4):
    fig = plt.figure(figsize=(20, 20))

    for i in range(n_filters):
        ax = fig.add_subplot(1, n_filters, i+1, xticks=[], yticks=[])
        # grab layer outputs
        ax.imshow(np.squeeze(layer[0,i].data.numpy()), cmap='gray')
        ax.set_title('Output %s' % str(i+1))
```

Let's look at the output of a convolutional layer after a ReLu activation function is applied.

In [6]:
```
# plot original image
plt.imshow(gray_img, cmap='gray')

# visualize all filters
fig = plt.figure(figsize=(12, 6))
fig.subplots_adjust(left=0, right=1.5, bottom=0.8, top=1, hspace=0.05, wspace=0.05)
for i in range(4):
    ax = fig.add_subplot(1, 4, i+1, xticks=[], yticks=[])
    ax.imshow(filters[i], cmap='gray')
    ax.set_title('Filter %s' % str(i+1))


# convert the image into an input Tensor
gray_img_tensor = torch.from_numpy(gray_img).unsqueeze(0).unsqueeze(1)

# get all the layers
conv_layer, activated_layer, pooled_layer = model(gray_img_tensor)

# visualize the output of the activated conv layer
viz_layer(activated_layer)
```

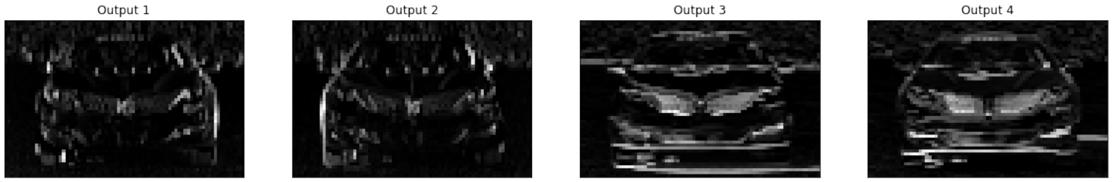




0.1.5 Visualize the output of the pooling layer

Then, take a look at the output of a pooling layer. The pooling layer takes as input the feature maps pictured above and reduces the dimensionality of those maps, by some pooling factor, by constructing a new, smaller image of only the maximum (brightest) values in a given kernel area.

```
In [7]: # visualize the output of the pooling layer
        viz_layer(pooled_layer)
```




```
In [ ]:
```