conv_layer_visualization

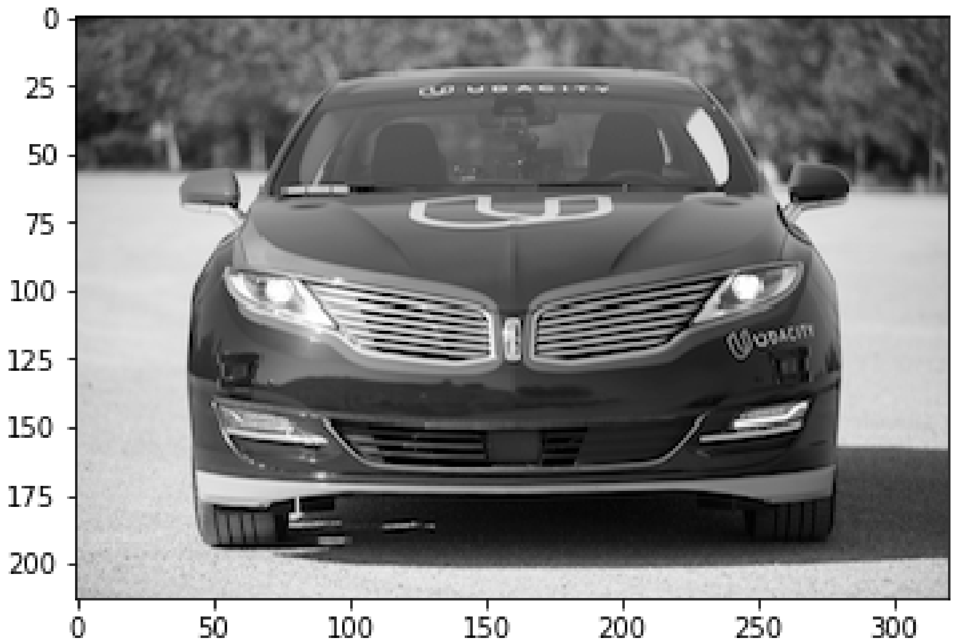
May 26, 2020

0.1 # Convolutional Layer

In this notebook, we visualize four filtered outputs (a.k.a. feature maps) of a convolutional layer.

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)
```

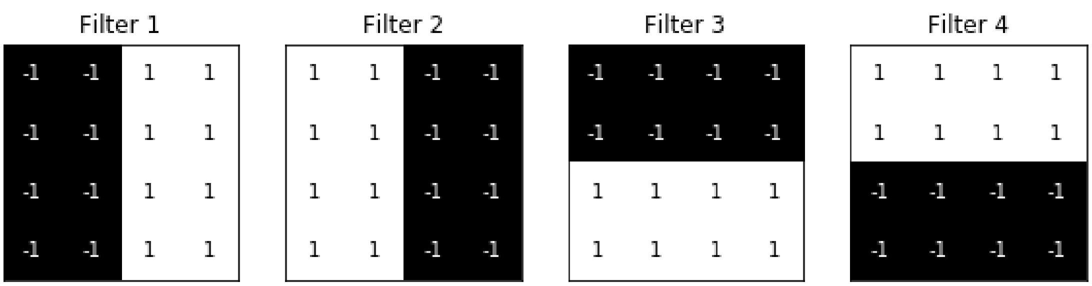
```
Filter shape:  (4, 4)
```

```
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]]

In [4]:
```
### do not modify the code below this line ###

# visualize all four filters
fig = plt.figure(figsize=(10, 5))
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))
    width, height = filters[i].shape
    for x in range(width):
        for y in range(height):
            ax.annotate(str(filters[i][x][y]), xy=(y,x),
                        horizontalalignment='center',
                        verticalalignment='center',
                        color='white' if filters[i][x][y]<0 else 'black')
```



0.1.3 Define a convolutional layer

Initialize a single convolutional layer so that it contains all your created filters. Note that you are not training this network; you are initializing the weights in a convolutional layer so that you can visualize what happens after a forward pass through this network!

In [5]:
```
import torch
import torch.nn as nn
import torch.nn.functional as F


# define a neural network with a single convolutional layer with four filters
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)

        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)

            # returns both layers
            return conv_x, activated_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)
)
```

0.1.4 Visualize the output of each filter

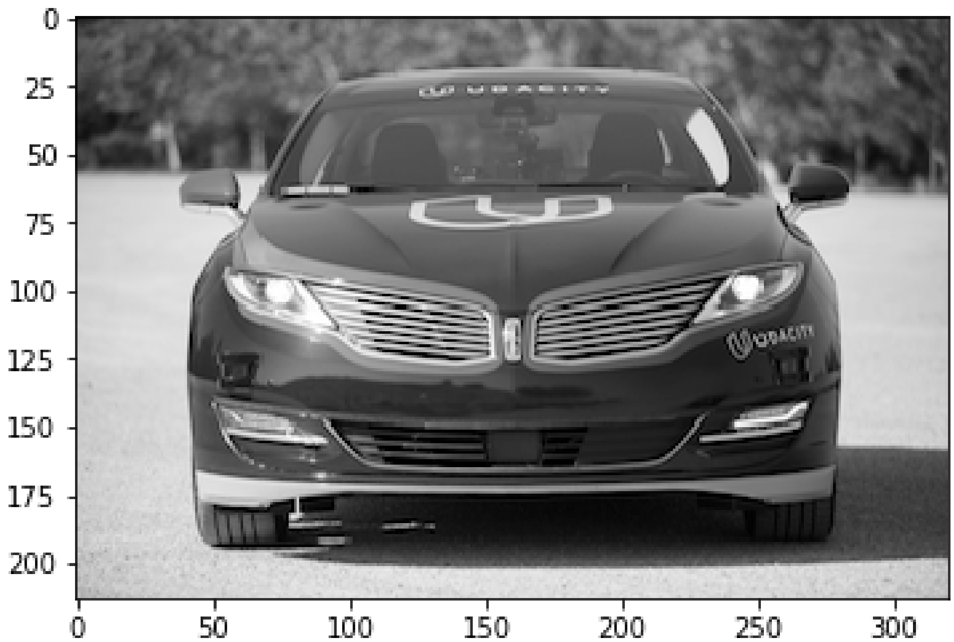
First, we'll define a helper function, `viz_layer` that takes in a specific layer and number of filters (optional argument), and displays the output of that layer once an image has been passed through.

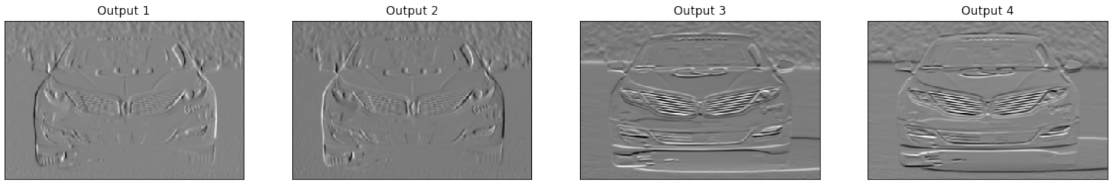
```
In [6]: # helper function for visualizing the output of a given layer
        # default number of filters is 4
        def viz_layer(layer, n_filters= 4):
            fig = plt.figure(figsize=(20, 20))

            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, before and after a ReLu activation function is applied.

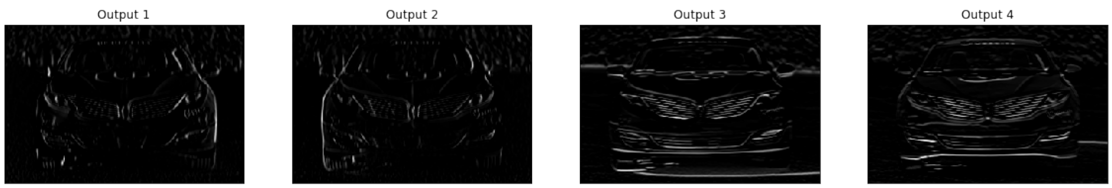
```
In [7]: # plot original image
        plt.imshow(gray_img, cmap='gray')
```

```python
# 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 the convolutional layer (pre and post activation)
conv_layer, activated_layer = model(gray_img_tensor)

# visualize the output of a conv layer
viz_layer(conv_layer)
```





In [8]:
```
# visualize the output of an activated conv layer
viz_layer(activated_layer)
```



In [ ]: