OpenCV

February 14, 2019

1 OpenCV

Prerequisite: Before starting this exercise, you should make yourself familiar with Python and some necessary library, e.g., numpy, matplotlib, etc. One good tutorial can be found here.

In this exercise you will: * Learn about some basic image processing operations with OpenCV. * Re-implement some basic image processing operations. This will help you to * Have better understand about the image processing operations. * Practice Python programming with Numpy library.

```
In [1]: import cv2
        import numpy as np
        import sys
        import matplotlib
        from matplotlib import pyplot as plt

        # This is a bit of magic to make matplotlib figures appear inline in the notebook
        # rather than in a new window.
        %matplotlib inline
        plt.rcParams['figure.figsize'] = (10.0, 8.0) # set default size of plots
        plt.rcParams['image.interpolation'] = 'nearest'
        plt.rcParams['image.cmap'] = 'gray'
```

```
In [2]: img = cv2.imread('imgs/grass.jpg')
        img = cv2.resize(img, (100, 100))
        print(img[:, :, 0])
        img[:, :, np.array([0, 1, 2])] = img[:, :, np.array([2, 1, 0])]
        print(img[:, :, 2])
```

```
[[16  7 17 ... 44 79 38]
 [28 28 30 ... 23 35 37]
 [22 24 34 ... 49 34 26]
 ...
 [86 49 24 ... 35 44 10]
 [30 30 31 ... 48 30 34]
 [23 25 41 ... 50 35 34]]
[[16  7 17 ... 44 79 38]
 [28 28 30 ... 23 35 37]
```

```
 [22 24 34 ... 49 34 26]
 ...
 [86 49 24 ... 35 44 10]
 [30 30 31 ... 48 30 34]
 [23 25 41 ... 50 35 34]]
```

```
In [3]: def rel_error(out, correct_out):
            return np.sum(abs(out.astype(np.float32) - correct_out.astype(np.float32)) /
                                      (abs(out.astype(np.float32)) + abs(correct_out.astype(np.floa
```

```
In [4]: # Checking OpenCV version
        cv2.__version__

Out[4]: '4.0.0'
```

1.0.1 NOTICE:

In this lab exercise, we recommend to use `OpenCV 3.x` version, the documentations for OpenCV API can be found here.

1.1 Load images

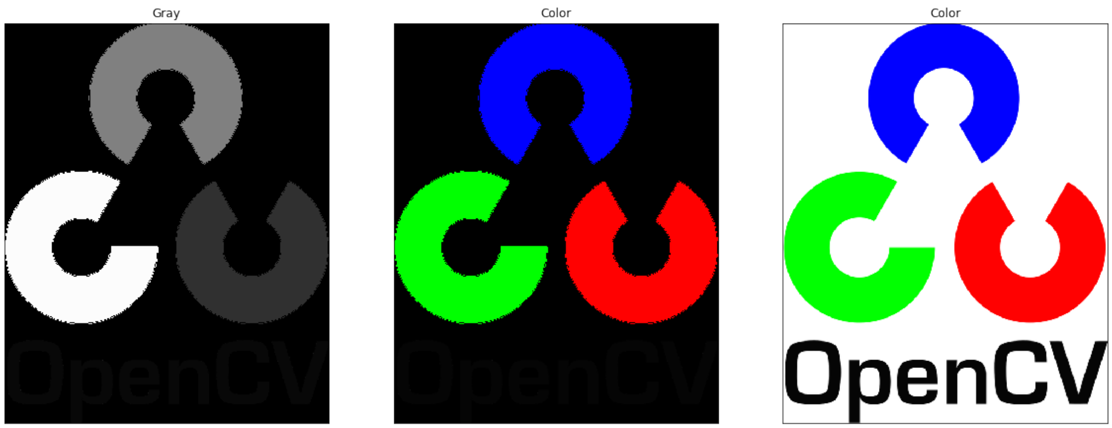
Use the function cv2.imread() to read an image. The image should be in the working directory or a full path of image should be given. The function will return a numpy matrix.
Second argument is a flag which specifies the way image should be read.

- cv2.IMREAD_COLOR - (1): Loads a color image. Any transparency (alpha channel) of image will be neglected. It is the **default flag**.
- cv2.IMREAD_GRAYSCALE - (0): Loads image in grayscale mode
- cv2.IMREAD_UNCHANGED - (-1): Loads image as such including alpha channel, if included.

NOTE: Color image loaded by OpenCV is in *Blue-Green-Red (BGR)* mode. But Matplotlib displays in *RGB* mode. So color images will not be displayed correctly in Matplotlib if image is read with OpenCV. We will discuss how to handle to display properly later.

```
In [5]: img_gray = cv2.imread('imgs/opencv_logo.png', 0)

        plt.figure(figsize=(20,10))
        plt.subplot(131),
        plt.imshow(img_gray, cmap='gray')  # include cmap='gray' to display gray image
        plt.title('Gray'),plt.xticks([]), plt.yticks([])

        img_color1= cv2.imread('imgs/opencv_logo.png', 1)
        plt.subplot(132),plt.imshow(img_color1),
        plt.title('Color'),plt.xticks([]), plt.yticks([])

        img_color2= cv2.imread('imgs/opencv_logo.png',-1)
```

```
plt.subplot(133),plt.imshow(img_color2),
plt.title('Color'),plt.xticks([]), plt.yticks([])
plt.show()
```



Question: How many channels for each image: img_gray, img_color1, img_color2?
Your answer: * img_gray: * img_color1: * img_color2:

2 Transformations

2.1 Scaling

Resize image using the function cv2.resize.

```
In [6]: # Get list of available flags
        flags = [i for i in dir(cv2) if i.startswith('INTER_')]
        print(flags)
```

```
['INTER_AREA', 'INTER_BITS', 'INTER_BITS2', 'INTER_CUBIC', 'INTER_LANCZOS4', 'INTER_LINEAR', 'I
```

```
In [7]: img = cv2.imread('imgs/opencv_logo1.png', 1)
        res = cv2.resize(img,None,fx=2.0, fy=2.0, interpolation = cv2.INTER_CUBIC)
        #OR
        height, width = img.shape[:2]
        res = cv2.resize(img,(2*width, 2*height), interpolation = cv2.INTER_CUBIC)

        ################################################################################
        # TODO: Check the size of 'img' and 'res'?

        ################################################################################
        print('Size of img:{}'.format(img.shape))
        print('Size of res:{}'.format(res.shape))
        ################################################################################
```

```
    #                                 END OF YOUR CODE                                #
    ###################################################################################

    ###################################################################################
    # TODO: Resize 'img' so as to the smaller side is 500, while keeping image
    # ratio unchanged.
    ###################################################################################
    aspect_ratio = img.shape[1]/img.shape[0]
    newimg = cv2.resize(img, (int(500*aspect_ratio),500), interpolation=cv2.INTER_CUBIC)
    print('Size of resizedimg:{}'.format(newimg.shape))
    ###################################################################################
    #                                 END OF YOUR CODE                                #
    ###################################################################################
```

```
Size of img:(378, 428, 3)
Size of res:(756, 856, 3)
Size of resizedimg:(500, 566, 3)
```

2.2 Translation

Translation is the shifting of object's location. If you know the shift in (x, y) direction, let it be (t_x, t_y), you can create the transformation matrix M as follows:

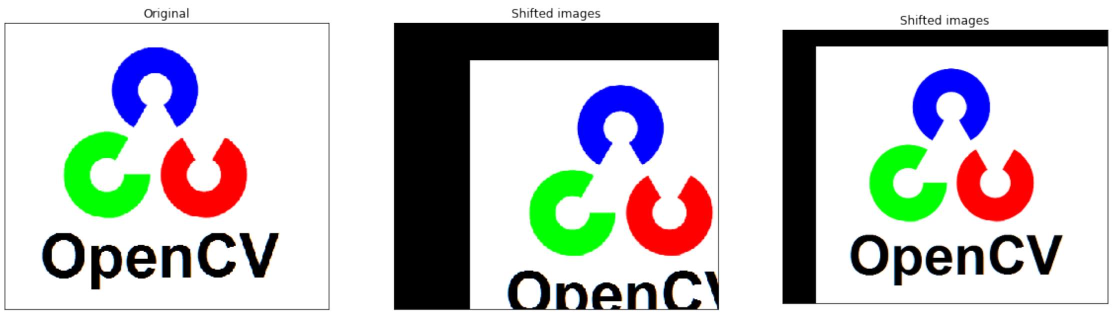
$$M = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \end{bmatrix}$$

You can take make it into a Numpy array of type **np.float32** and pass it into cv2.warpAffine() function.

```
In [8]: img = cv2.imread('imgs/opencv_logo1.png', 1)
        rows,cols,_ = img.shape
        M = np.float32([[1,0,100],[0,1,50]]) # Shift right by 100 and down by 50
        dst = cv2.warpAffine(img,M,(cols,rows))
        print(res.shape)
        ###################################################################################
        # TODO: Observed that the bottom right of 'dst' image is lost. Modifying the
        # following codeline so as to the 'res' image is fully shown.
        ###################################################################################
        resizedres = cv2.warpAffine(res, M, dsize = (956,806))
        ###################################################################################
        #                                 END OF YOUR CODE                                #
        ###################################################################################

        plt.figure(figsize=(20,10))
        plt.subplot(131),plt.imshow(img),
        plt.title('Original'),plt.xticks([]), plt.yticks([])
        plt.subplot(132),plt.imshow(dst),
        plt.title('Shifted images'),plt.xticks([]), plt.yticks([])
```

```
plt.subplot(133),plt.imshow(resizedres),
plt.title('Shifted images'),plt.xticks([]), plt.yticks([])
plt.show()
```

```
(756, 856, 3)
```



2.3 Rotation

Calculates an affine matrix of 2D rotation using cv2.getRotationMatrix2D(). * 1st argument: center * 2nd argument: angle (in degree) * 3rd argument: scale

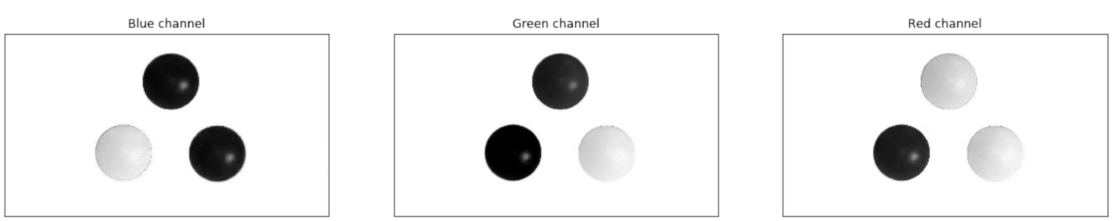
```
In [9]: img = cv2.imread('imgs/opencv_logo1.png', 1)
        H,W,_ = img.shape
        ################################################################################
        # TODO: Run the code to observe the output image.
        # Modify the code below so as to the 'dst' image has no black padding.
        ################################################################################
        adjusted = cv2.getRotationMatrix2D((H/1.76,W/2), 90, 1)
        newimg = cv2.warpAffine(img, adjusted, (H,W))
        ################################################################################
        #                                END OF YOUR CODE                              #
        ################################################################################

        plt.imshow(newimg),
        plt.title('Rotated images'),plt.xticks([]), plt.yticks([])
        plt.show()
```

3 Changing color space - Grayscale

Grayscale values is converted from RGB values by a weighted sum of the R, G, and B components:

$$0.299 \times R + 0.587 \times G + 0.114 \times B$$

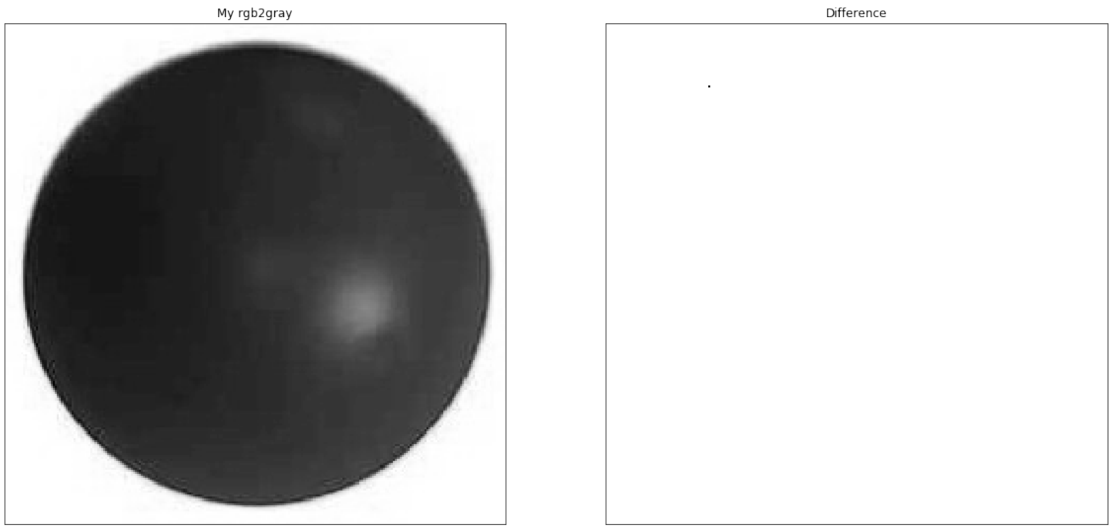
In [10]:
```
# Split channels
img = cv2.imread('imgs/balls.jpg', 1)

plt.figure(figsize=(20,10))
plt.subplot(131),plt.imshow(img[:,:,0], cmap='gray'),
plt.title('Blue channel'),plt.xticks([]), plt.yticks([])
plt.subplot(132),plt.imshow(img[:,:,1], cmap='gray'),
plt.title('Green channel'),plt.xticks([]), plt.yticks([])
plt.subplot(133),plt.imshow(img[:,:,2], cmap='gray'),
plt.title('Red channel'),plt.xticks([]), plt.yticks([])
plt.show()
```



```
In [11]: def rgb2gray(img):
             """
             A implementation of the method that converts BGR image to grayscale image of
             uint8 data type.
             """
             out = 0.114*img[:,:,0] + 0.587*img[:,:,1] + 0.299*img[:,:,2]
              ################################################################################
             # TODO: Implement the method to convert BGR image to Grayscale image.         #
             # Hint: Remember to round and convert the values to nearest uint8 values.      #
             ################################################################################
             out = np.round(out)
             ################################################################################
             #                                  END OF YOUR CODE                            #
             ################################################################################

             return out
```

Run the following code section to compare your implementation of the `rgb2gray` function with OpenCV built-in function cv2.cvtColor.

```
In [12]: img = cv2.imread('imgs/ball_red.jpg', 1)
         img_gray1 = rgb2gray(img)
         img_gray2 = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

         plt.figure(figsize=(20,10))
         plt.subplot(121),plt.imshow(img_gray1, cmap='gray'),
         plt.title('My rgb2gray'),plt.xticks([]), plt.yticks([])
         plt.subplot(122),plt.imshow(img_gray1 - img_gray2, cmap='gray'),
         plt.title('Difference'),plt.xticks([]), plt.yticks([])
         plt.show()

         # Check your output: count
         print('Testing rgb2gray')
         print('Number of difference pixel is %d' % np.count_nonzero(img_gray1 - img_gray2))
```




```
Testing rgb2gray
Number of difference pixel is 1
```

Question: Does your implementation of `rgb2gray` function give the result that is exactly the same as OpenCV built-in function? Why?

Your answer: fill in here

No it does not. It differs by 1 due to numeric calculation differences

4 Changing color space - Detect object by color.

By converting BGR image to HSV, we can use this to extract a colored object. In HSV, it is more easier to represent a color than RGB color-space. In this exercise, we will try to extract blue, red, and yellow colored objects. So here is the method:

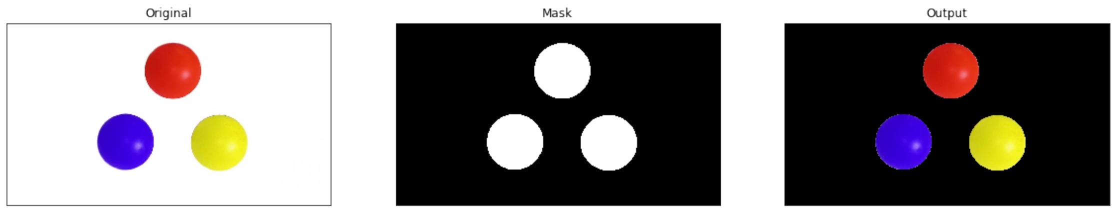
- Take each frame of the video
- Convert from BGR to HSV color-space
- We threshold the HSV image for a range of blue color
- Now extract the blue object alone, we can do whatever on that image we want.

```
In [13]: # Get list of available flags
         flags = [i for i in dir(cv2) if i.startswith('COLOR_')]
         print (flags)
```

```
['COLOR_BAYER_BG2BGR', 'COLOR_BAYER_BG2BGRA', 'COLOR_BAYER_BG2BGR_EA', 'COLOR_BAYER_BG2BGR_VNG
```

```
In [14]: frame = cv2.imread('imgs/balls.jpg', 1)
```

```python
# Convert BGR to RGB, now you will see the color of 'frame' image
# is displayed properly.
frame = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)

# Convert BGR to HSV
hsv = cv2.cvtColor(frame, cv2.COLOR_RGB2HSV)

# define range of blue color in HSV
lower_blue = np.array([110,50,50])
upper_blue = np.array([130,255,255])

# Threshold the HSV image to get only blue colors
mask = cv2.inRange(hsv, lower_blue, upper_blue)

# Bitwise-AND mask and original image
res = cv2.bitwise_and(frame, frame, mask= mask)

################################################################################
# TODO: Implement masks for red and yellow balls.
################################################################################
lower_red = np.array([0, 100, 100])
upper_red = np.array([255, 255, 255])
red_mask = cv2.inRange(hsv, lower_red, upper_red)
res = cv2.bitwise_and(frame, frame, mask= red_mask)

# lower_green = np.array([50,110,50])
# upper_green = np.array([255,130,255])
# green_mask = cv2.inRange(hsv, lower_green, upper_green)
# res = cv2.bitwise_and(frame, frame, mask= green_mask)

################################################################################
#                                  END OF YOUR CODE                            #
################################################################################

plt.figure(figsize=(20,10))
plt.subplot(131),plt.imshow(frame),
plt.title('Original'),plt.xticks([]), plt.yticks([])
plt.subplot(132),plt.imshow(red_mask, cmap='gray'),
plt.title('Mask'),plt.xticks([]), plt.yticks([])
plt.subplot(133),plt.imshow(res),
plt.title('Output'),plt.xticks([]), plt.yticks([])
plt.show()
```



5 2D Convolution (Image Filtering)

OpenCV provides a function, cv2.filter2D, to convolve a kernel with an image.

```
In [15]: def convolution_naive(x, F, conv_param):
             """
             A naive implementation of a convolutional filter.

             The input consists of a gray scale image x (1 channel) with height H and width
             W. We convolve each input with filter F, which has height HH and width HH.

             Input:
             - x: Input data of shape (H, W)
             - F: Filter weights of shape (HH, WW)
             - conv_param: A dictionary with the following keys:
               - 'stride': The number of pixels between adjacent receptive fields in the
                 horizontal and vertical directions.
               - 'pad': The number of pixels that will be used to zero-pad the input.

             Return:
             - out: Output data, of shape (H', W') where H' and W' are given by
               H' = 1 + (H + 2 * pad - HH) / stride
               W' = 1 + (W + 2 * pad - WW) / stride
             """

             stride = conv_param['stride']
             pad = conv_param['pad']

             H, W = x.shape
             HH, WW = F.shape
             frame = (WW - 1) // 2
             H_prime = int(1 + (H + 2 * pad - HH) / stride)
             W_prime = int(1 + (W + 2 * pad - WW) / stride)
             #print(H_prime,W_prime)
             x_pad = np.lib.pad(x, ((pad, pad), (pad, pad)),\
                                'constant', constant_values=(0))
             out = np.zeros((H_prime, W_prime), dtype=x.dtype)
             print(x_pad.shape)
```

```
    ###########################################################################
    # TODO: Implement the convolutional forward pass.                         #
    # Hint: Using 2 nested for-loop to calculate each pixel of the output image.#
    ###########################################################################
    for i in range(pad, H+pad):
        for j in range(pad, W+pad):
            roi = x_pad[i - pad:i + pad + 1, j - pad:j + pad + 1]
            k = (roi * F).sum()
            out[i - pad, j - pad] = k
    ###########################################################################
    #                             END OF YOUR CODE                            #
    ###########################################################################
    return out
```

Run the following code section to test your implementation of the `convolution_naive` function

```
In [16]: x_shape = (5, 5)
         F_shape = (3, 3)
         x = np.linspace(-0.1, 0.5, num=np.prod(x_shape)).reshape(x_shape)
         F = np.linspace(-0.2, 0.3, num=np.prod(F_shape)).reshape(F_shape)
         conv_param = {'stride': 1, 'pad': 1}

         out = convolution_naive(x, F, conv_param)
         correct_out = np.array( [[ 0.0075,     0.030625,   0.0521875,  0.07375,    0.0475   ]
                                  [ 0.114375,   0.1725,     0.18375,    0.195,      0.10875  ]
                                  [ 0.1753125,  0.22875,    0.24,       0.25125,    0.1228125]
                                  [ 0.23625,    0.285,      0.29625,    0.3075,     0.136875 ]
                                  [ 0.0075,    -0.05375,   -0.0603125, -0.066875,  -0.1025   ]]
         # print(correct_out.shape)
         # print(out)

         # Compare your output to ours; difference should be very small
         print('Testing convolution_naive')
         print('difference: ', rel_error(out, correct_out))
```

```
(7, 7)
Testing convolution_naive
difference:  0.0
```

```
In [17]: # List of available BORDER effect
         flags = [i for i in dir(cv2) if i.startswith('BORDER_')]
         print (flags)
```

```
['BORDER_CONSTANT', 'BORDER_DEFAULT', 'BORDER_ISOLATED', 'BORDER_REFLECT', 'BORDER_REFLECT101'
```

5.1 Averaging filter

This is done by convolving image with a normalized box filter. A 5×5 normalized box filter would look like below:

$$K = \frac{1}{25}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

In [18]:
```
# Convert image data type from uint8 to float32.
img = cv2.imread('imgs/text.png', 1).astype(np.float32)
img = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

kernel = np.zeros((5,5), np.float32)
################################################################################
# TODO: Create a 5x5 kernel as K shown above.                                  #
################################################################################
kernel = np.ones((5,5), np.float32)/25
################################################################################
#                                  END OF YOUR CODE                            #
################################################################################
blur_2dfilter = cv2.filter2D(img,-1,kernel)

# The above codes can be replaced by the following code line.
blur = cv2.blur(img,(5,5))

# Check your output; difference should be around 4e-3
print('Testing convolution_naive')
print('difference: ', rel_error(blur_2dfilter, blur))


# Visualize the output image
plt.figure(figsize=(20,10))
plt.subplot(121),plt.imshow(img, cmap='gray'),
plt.title('Original'),plt.xticks([]), plt.yticks([])
plt.subplot(122),plt.imshow(blur, cmap='gray'),
plt.title('Average Blur'),plt.xticks([]), plt.yticks([])
plt.show()
```

```
Testing convolution_naive
difference:  0.0035883125
```