Image Generation, Processing & Understanding with Python

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Chapter 1

Preparation & Documents

1. `python 3.x`
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3. OpenCV-Python Tutorial
4. docs.opencv.org
5. Python Image Library: Pillow
6. scikit-image.org
7. github.com/opencv

Chapter 2

Pixelwise Operations

2.1 Blending Two Images

$$I_B = \alpha I_1 + (1-\alpha) I_2, \quad \alpha \in [0,1]$$

Procedure:

1. prepare two image files
2. read the two files
3. set α to a value, e.g. 0.5
4. compute the weighted sum of the two images
5. display the result

Notice:

- `np.uint8` is the type of a pixel value for display.
- BGR in OpenCV!

Try:

- make a video showing a progressive change from one image to another by increasing α from 0 to 1 smoothly.

```
# filename blending.py

import sys
import numpy as np
import cv2
import matplotlib
matplotlib.use ('TkAgg')
import matplotlib.pyplot as plt


size = (256, 300)
# read two images
```

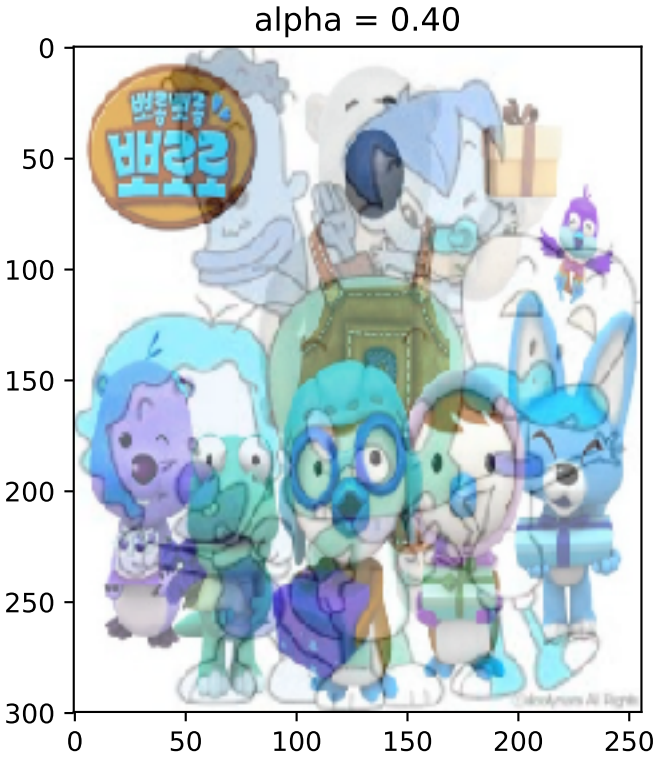
```
file1 = 'data/dooly.jpeg'
i1 = cv2.imread (file1)
if i1 is None:
    print ('image file read error: ', file1)
    sys.exit()

i1 = cv2.resize(i1, size)

file2 = 'data/pororo.jpeg'
i2 = cv2.imread (file2)
if i2 is None:
    print ('image file read error: ', file2)
    sys.exit()

i2 = cv2.resize (i2, size)

results = []
alphas = np.linspace(0, 1, 6)  # allocate alpha values
print ('alpha: ', alphas)
```

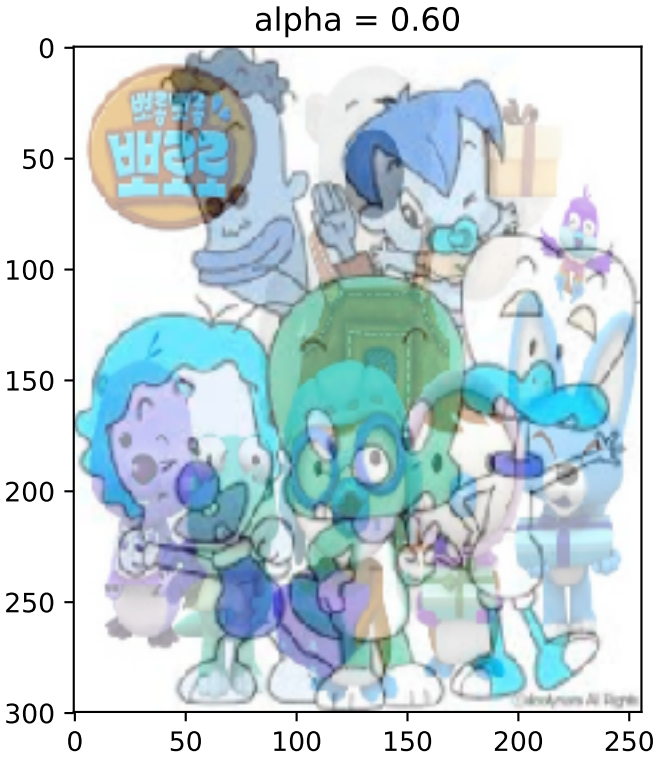
```
## alpha:  [0.  0.2 0.4 0.6 0.8 1. ]
```

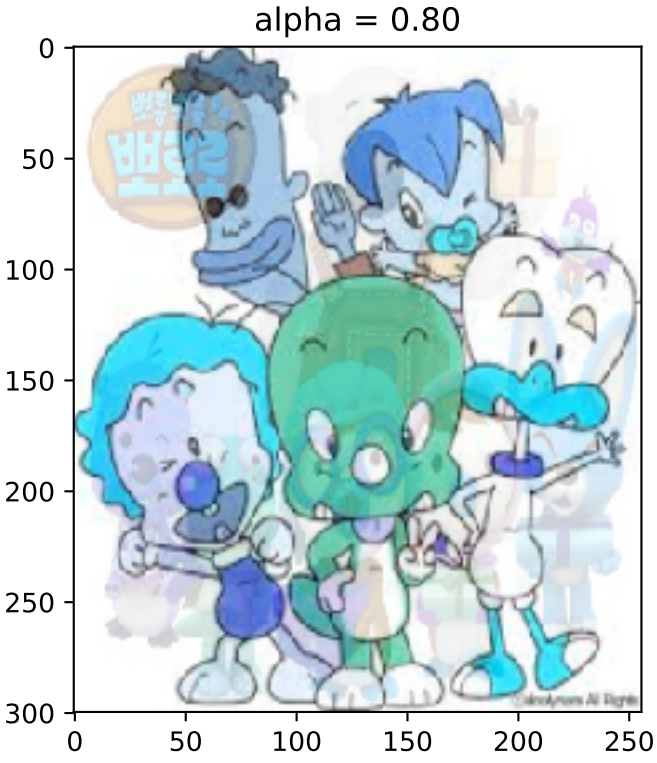
```
for a in alphas:
    J = a * i1 + (1. - a) * i2
    J = np.clip(J, 0, 255).astype(np.uint8)
    results.append (J)
    print (a)
    plt.imshow (J)
    plt.title ('alpha = %.2f' % a)
    plt.pause (1)
#
```

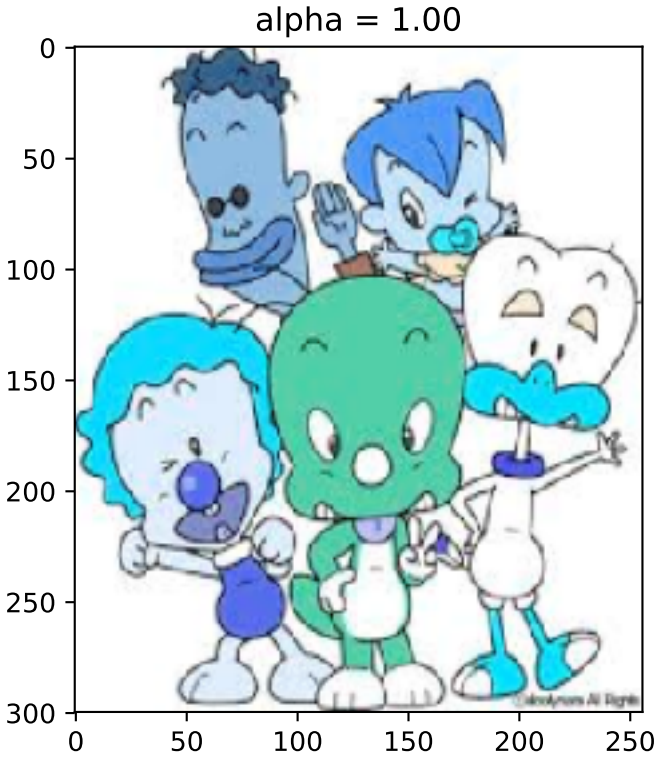

alpha = 0.00
0
50
100
150
200
250
300
0
50
100
150
200
250


alpha = 0.20
0
50
100
150
200
250
300
0
50
100
150
200
250

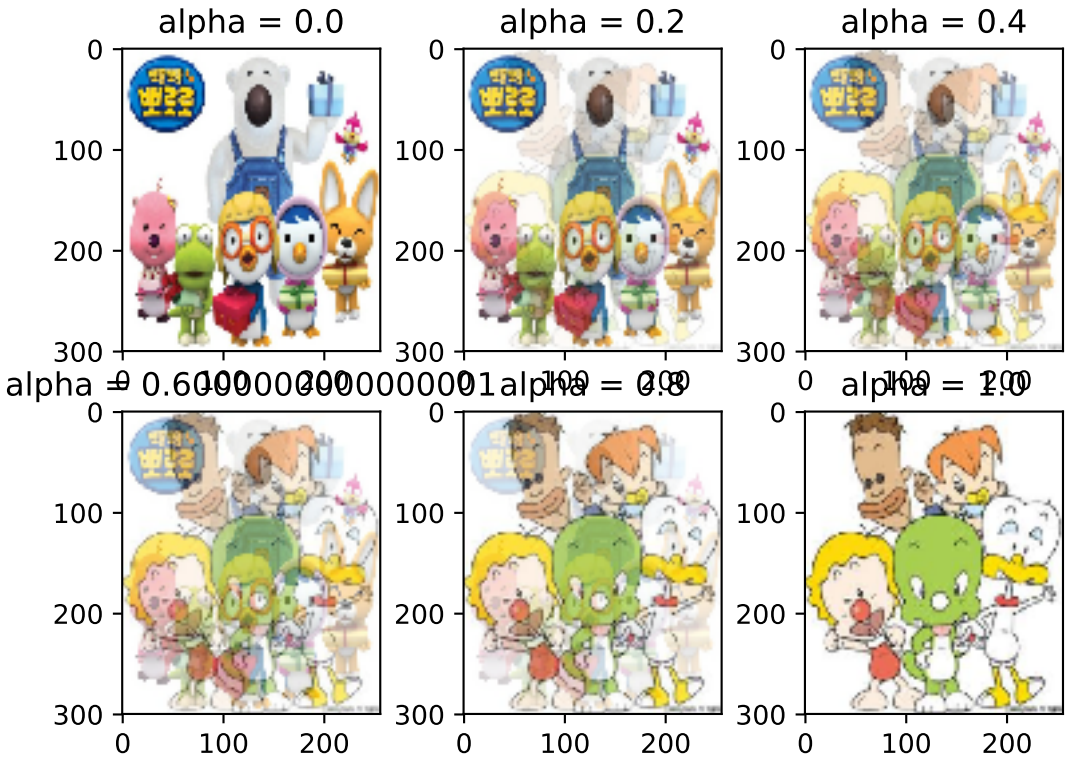

alpha = 0.40
0
50
100
150
200
250
300
0
50
100
150
200
250


alpha = 0.60
0
50
100
150
200
250
300
0
50
100
150
200
250


alpha = 0.80
0
50
100
150
200
250
300
0
50
100
150
200
250




```
fig, axes = plt.subplots (2, 3)
for i, ax in enumerate(axes.ravel()):
    ax.imshow (results[i][:,:,::-1]) # BGR -> RGB
    ax.set_title ('alpha = {}'.format(alphas[i]))
#
plt.pause (2)
```



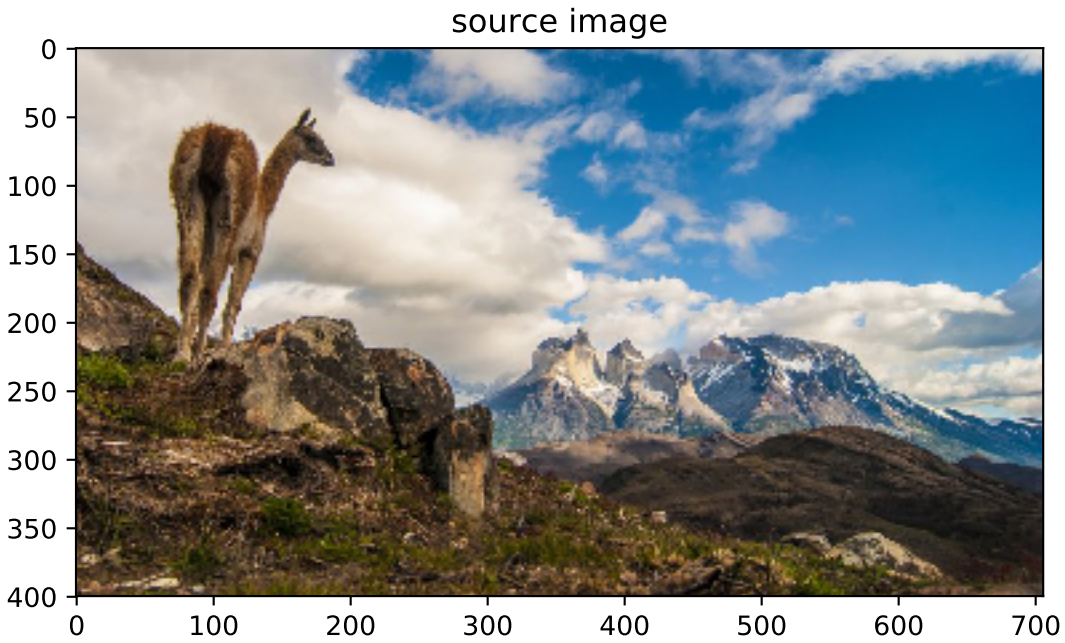

```
plt.close()

# EOF
```

2.2 Negative Film Effect

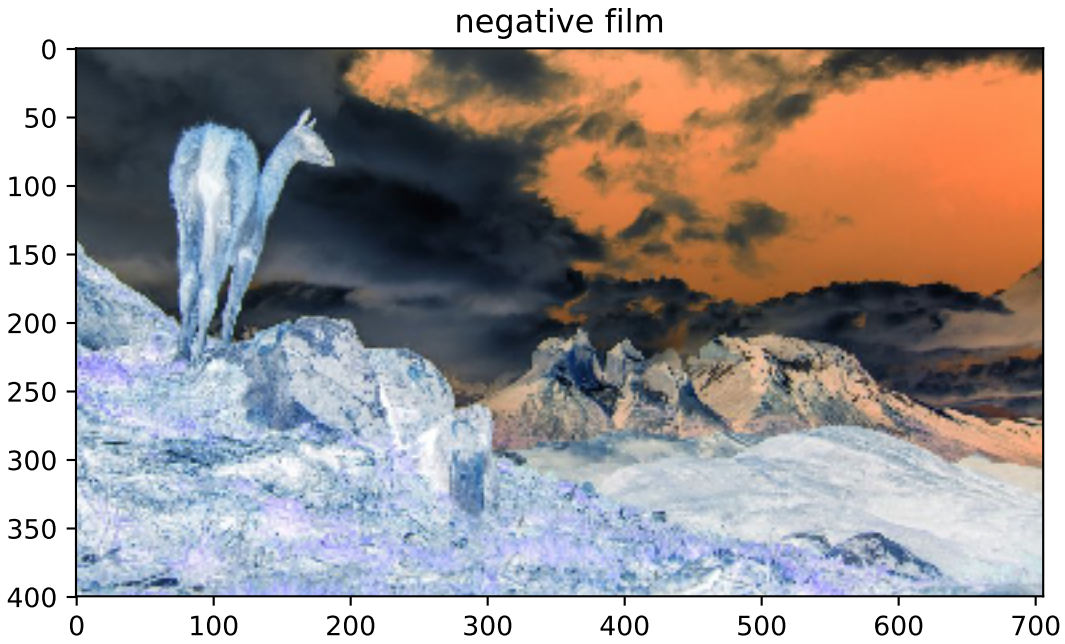
The image looks like a negative film in old days.

```
# filename negative_film.py

import sys
import numpy as np
import cv2
import matplotlib
matplotlib.use ('TkAgg')
import matplotlib.pyplot as plt
import imageio # this will be used to load an image file

# show the image
def imshow (img, title=None):
    plt.imshow (img)
    if title is None: title = 'imshow'
    plt.title (title)
    plt.pause (1)
```

```
    plt.close ()
#

def negative_film (img):
#    return 255 - img  # simple way using numpy.
    neg = np.zeros_like (img)
    for r in range (img.shape[0]):
        for c in range (img.shape[1]):
            for d in range (img.shape[2]):
                neg[r,c,d] = 255 - img[r,c,d]
    return neg
#

img = imageio.imread ('data/torres-del-paine.jpg')

imshow (img, 'source image')
```




```
neg = negative_film (img)

imshow (neg, 'negative film')

# EOF
```

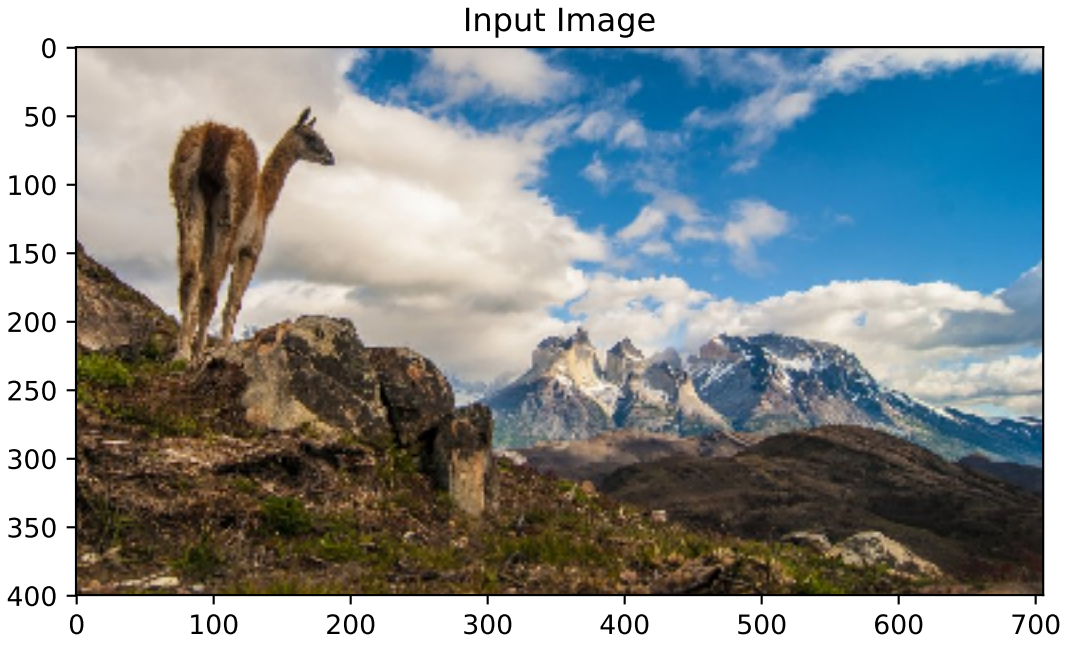


2.3 Histogram of RGB numpy image

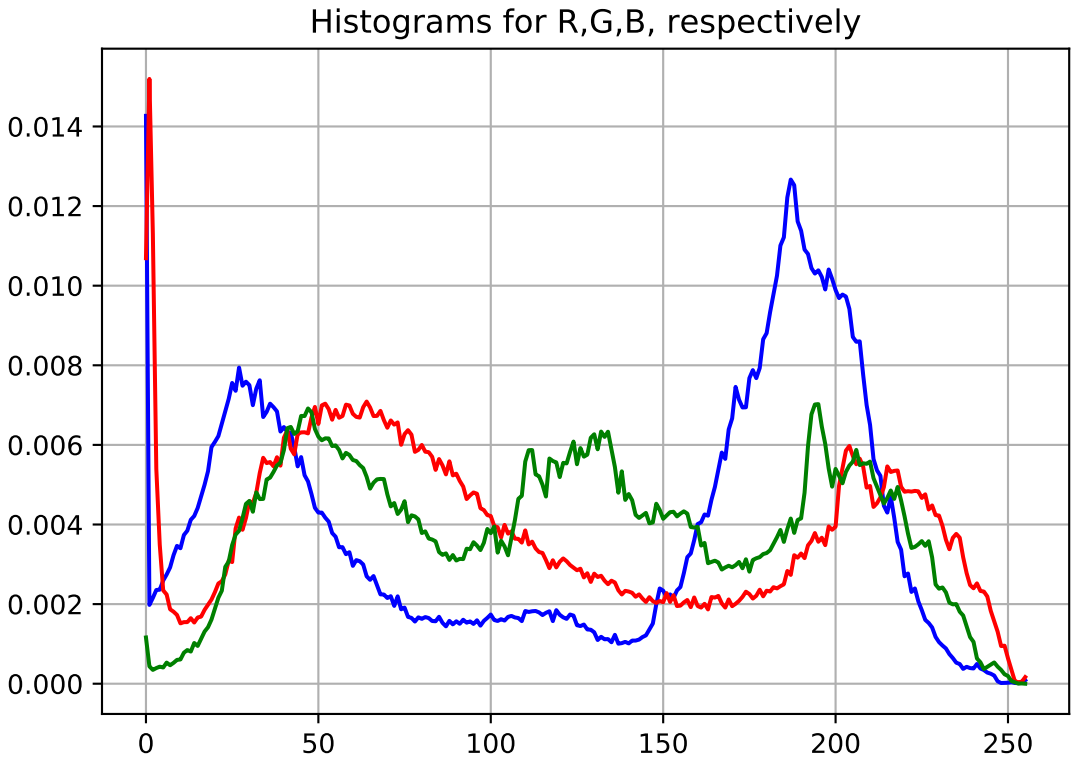
```
# filename: numpy-hist.py

import sys
import matplotlib.pyplot as plt
import numpy as np
import cv2

imagefile = 'data/torres-del-paine.jpg'

frame = cv2.imread(imagefile)

bluehist = np.zeros((256), dtype=np.float)
redhist = np.zeros((256), dtype=np.float)
greenhist = np.zeros((256), dtype=np.float)

# make histograms, one for each color
for r in range(frame.shape[0]):
    for c in range(frame.shape[1]):
        blue_intensity = frame[r,c][0]
        bluehist[blue_intensity] += 1
        redhist[frame[r,c,2]] += 1
```

```
        greenhist[frame[r,c][1]] += 1
#

# convert to ratio = count / num_pixels
num_pixels = frame.shape[0] * frame.shape[1]
bluehist /= num_pixels
greenhist /= num_pixels
redhist /= num_pixels

plt.imshow (frame[:,:,::-1]) ## cv2's BGR -> RGB
plt.title ('Input Image')
plt.pause (1)
plt.close()

x = range(0,256,1)
plt.plot (x, bluehist, 'b', x, redhist, 'r', x, greenhist, 'g')
plt.grid(True)
plt.title ('Histograms for R,G,B, respectively')
plt.pause (1)
plt.close ()

#EOF
```

A result of the program is shown below.




```
## [<matplotlib.lines.Line2D object at 0x7fd5989130b8>, <matplotlib.lines.Line2D object at 0x7fd598913
```

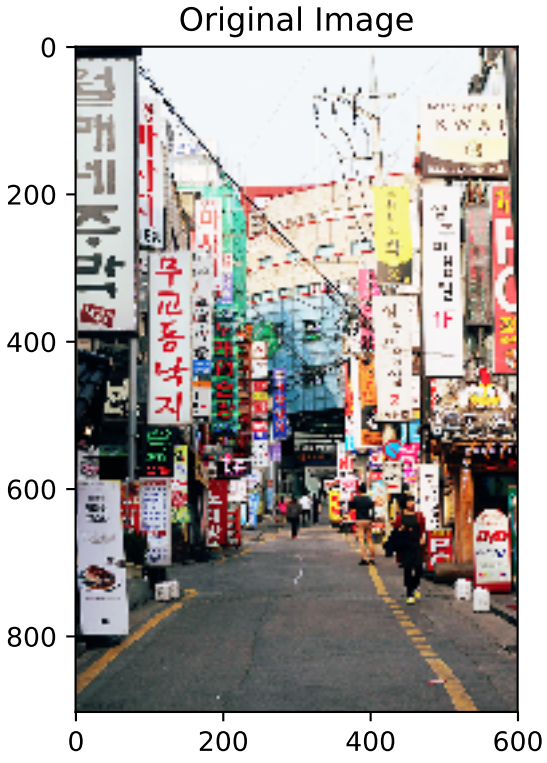

Histograms for R,G,B, respectively
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
50
100
150
200
250

Chapter 3

Float32 Pixel Representation

- `uint8` is a popular choice. 24bit representation.
- `float32` for $[0, 1]$ pixel values is another choice.
- One RGB pixel occupies 3×32bits or 12byte representation.
- TIF image file format can be used to save images of `float32` pixel data.

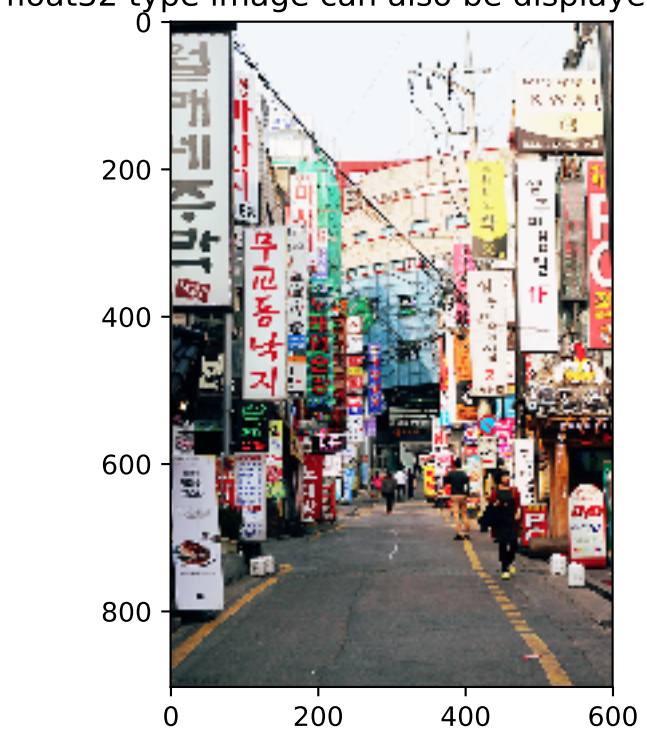
```
# filename: float-image-type.py

# image pixel data is represented normally by uint8
# but float32 is also a popular representation.
# Use TIF format to save a float32 RGB image
# Image Viewer for TIF float32 is ImageMagick/display

import imageio
import matplotlib.pyplot as plt
import numpy as np

im = imageio.imread ('data/imgKorea012.png')
plt.imshow (im)
plt.title('Original Image')
plt.pause(1); plt.close()

# convert to float type image in the rage [0, 1.]
```




```
im = np.float32(im / 255.)
print ('float32 image: ', im.dtype, im[100,100])
```

```
## float32 image:  float32 [0.95686275 0.9764706  0.9764706 ]
```

```
plt.imshow (im)
plt.title ('float32 type image can also be displayed by plt.')
plt.pause(1); plt.close()

# automatic conversion to uint8 is provided.
```




```
png_filename = 'data/imgKorea012-float32.png'
imageio.imwrite(png_filename, im)
```

```
## Lossy conversion from float32 to uint8. Range [0, 1]. Convert image to uint8 prior to saving to suppr
```

```
im2 = imageio.imread(png_filename)
print ('png file reloaded: ', im2.dtype, im2[100,100])

#
```

```
## png file reloaded:  uint8 [244 249 249]
```

```
tif_filename = 'data/imgKorea012-float32.tif'
imageio.imwrite (tif_filename, im)
imtif = imageio.imread(tif_filename)
print ('tif file reloaded: ', imtif.dtype, imtif[100,100])
```

```
## tif file reloaded:  float32 [0.95686275 0.9764706  0.9764706 ]
```

```
plt.imshow (imtif)
plt.title ('TIF image format can save float32 type image.')
plt.pause(1); plt.close()

#
```


```
import cv2
imcv = cv2.imread (tif_filename)
if imcv is None:
    print ('tif float32 cannot be loaded by cv2.imread()')
else:
    print ('tif loaded by cv2: {}'.format(imcv.shape))
#
# EOF
```

```
## tif float32 cannot be loaded by cv2.imread()
```

Chapter 4

Geometric Transformations

1. Translation
2. Scaling (magnifying x2)
3. interpolation
4. Rotation
5. Matrix Notation & Homogeneous Coordinate Representation
6. Similarity Transformation
7. Affine Tranformation
8. Projective (Perspective) Transformation

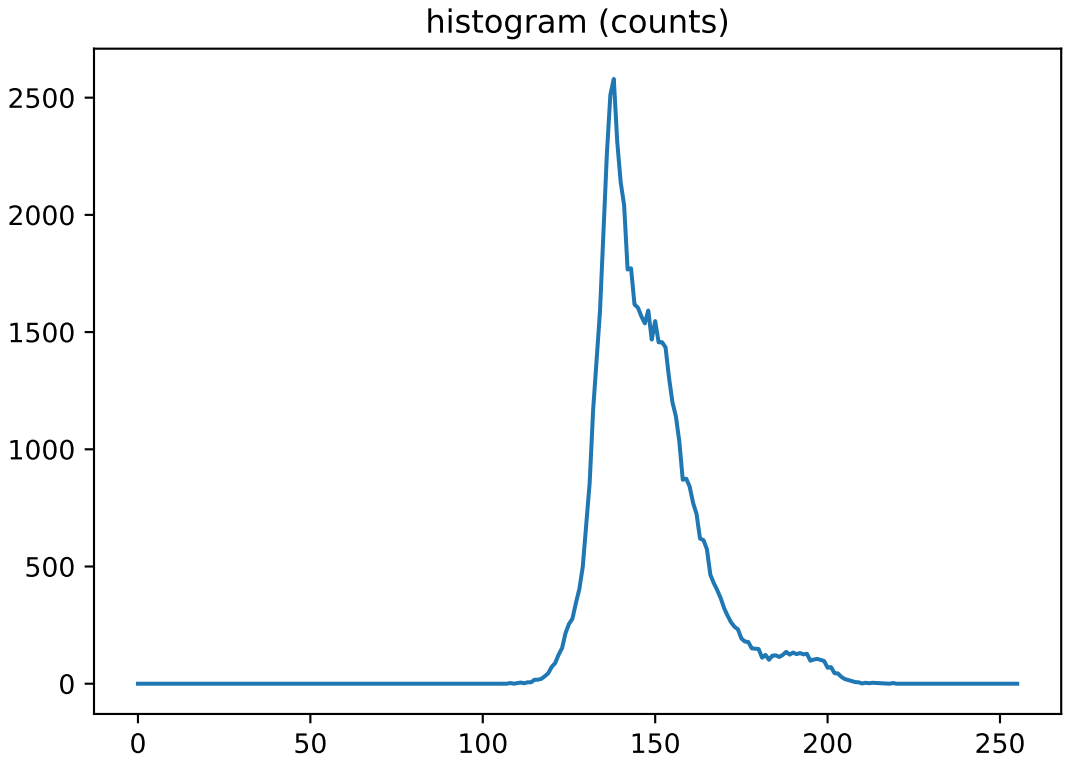
Chapter 5

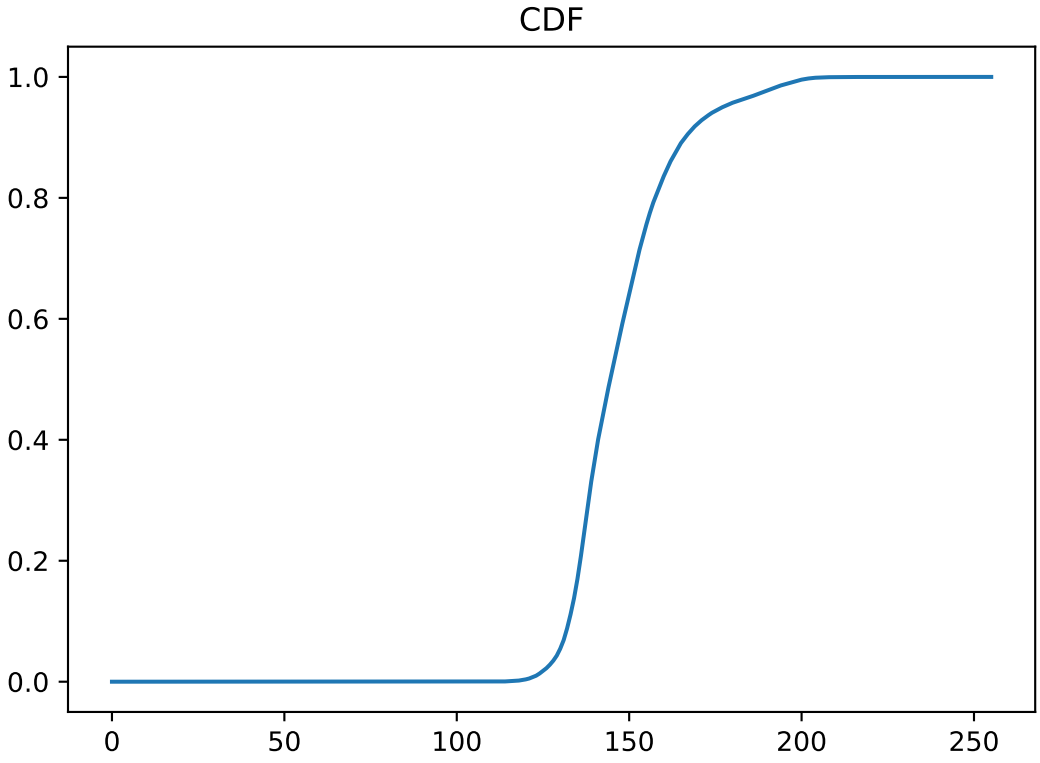
Histogram Equalization

- Check Wikipedia Histogram Equalization

```
## image size (gray scale):  (200, 300)
```

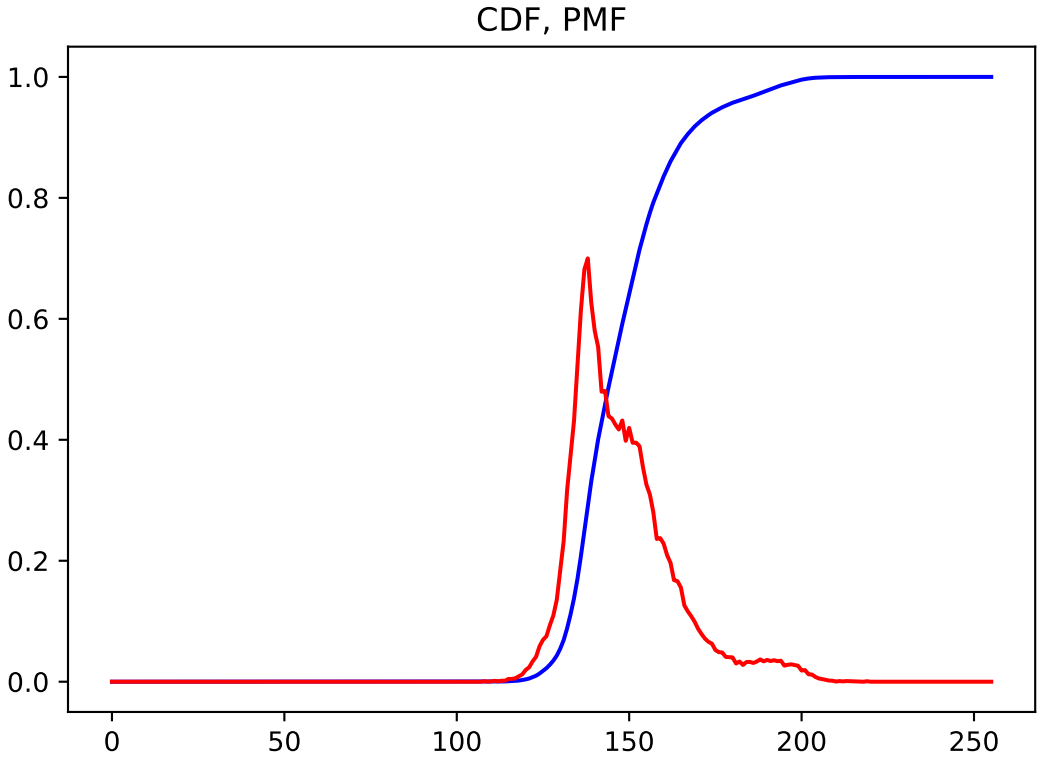

```
## cdf:  (256,)
```

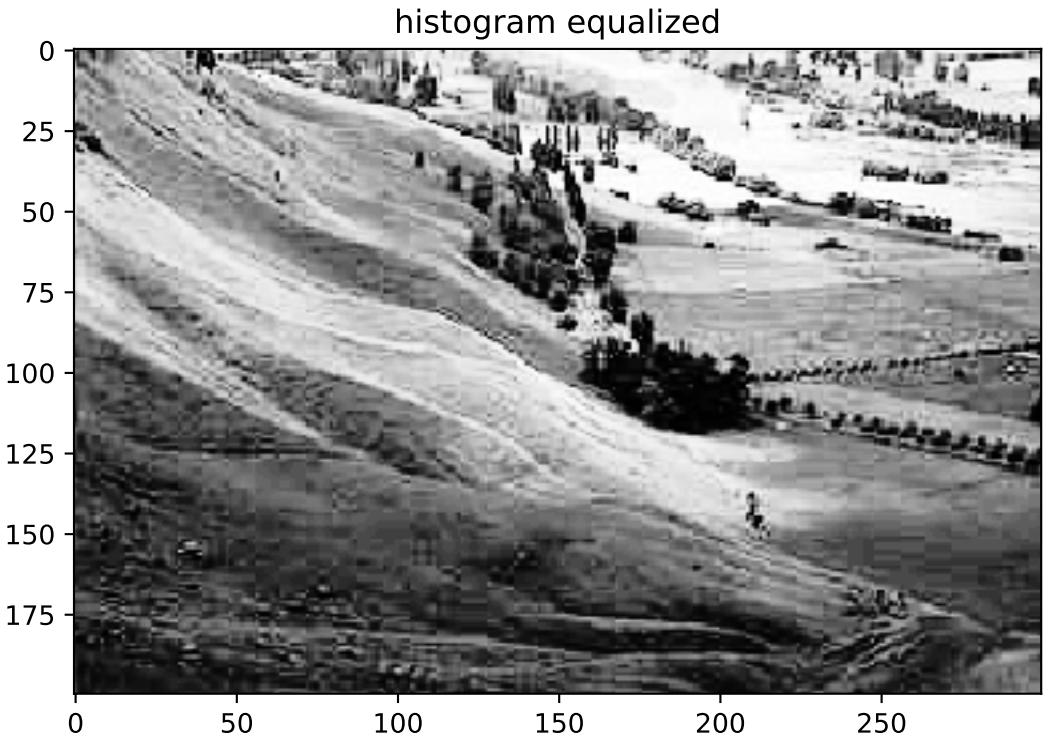

histogram (counts)
2500
2000
1500
1000
500
0
0
50
100
150
200
250



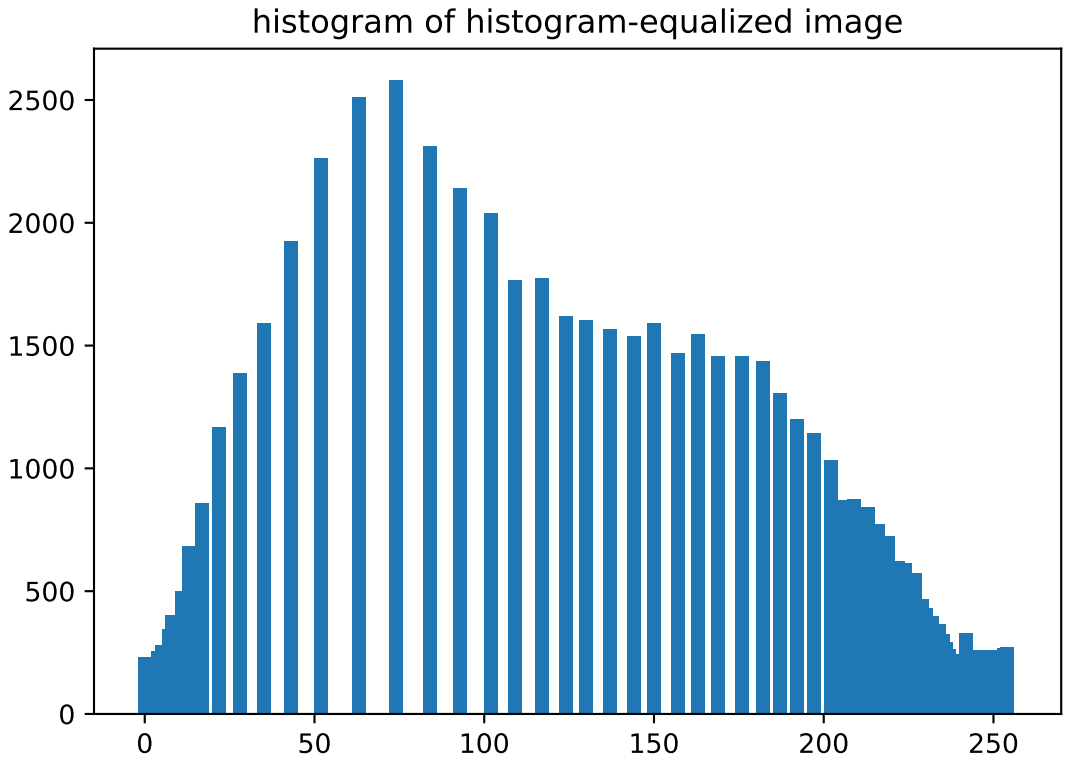

```
## max of pmf:  0.043
```

```
## [<matplotlib.lines.Line2D object at 0x7fd597bc9898>, <matplotlib.lines.Line2D object at 0x7fd564de09
```


CDF, PMF
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250




```
## <BarContainer object of 256 artists>
```




```
# filename: histogram_equalization.py
# https://en.wikipedia.org/wiki/Histogram_equalization

import cv2
import numpy as np
import matplotlib
matplotlib.use('TkAgg')
import matplotlib.pyplot as plt

imagefilename = 'data/300px-Unequalized_Hawkes_Bay_NZ.jpg'
img = cv2.imread(imagefilename, cv2.IMREAD_GRAYSCALE)
print ('image size (gray scale): ', img.shape)

plt.imshow (img, cmap='gray')
plt.pause (1)
plt.close()

def histogram (ii):
    h = np.zeros(256)
    for val in ii.flatten():
        h[val] += 1
    return h
#

def make_cdf (pmf):
    cdf = np.zeros (pmf.shape)
```

```
    print ('cdf: ', cdf.shape)
    cdf[0] = pmf[0]
    for x in range(1, cdf.shape[0]):
        cdf[x] = cdf[x-1] + pmf[x]
    return cdf
#

# compute histogram
h = histogram (img)

# normalize to get PMF, Probability Mass Function
pmf = h / float(img.shape[0]*img.shape[1])

# Accumulate to get CDF, Cumulative Distribution Function
cdf = make_cdf (pmf)

plt.plot (h); plt.title ('histogram (counts)') # show the histogram
plt.pause (1) # seconds
plt.close()

plt.plot (cdf); plt.title('CDF') # check the CDF
plt.pause (1)
plt.close()

#
pmf_max = pmf.max()
print ('max of pmf: ', pmf_max)
plt.plot (range(cdf.shape[0]), cdf, 'b-', range(cdf.shape[0]), pmf*0.7/pmf_max, 'r-');
plt.title ('CDF, PMF')
plt.pause(1)
plt.close()

def histogram_equalization (img, cdf):
    ieq = np.zeros_like (img)
    for r in range(img.shape[0]):
        for c in range(img.shape[1]):
            pixelvalue = img[r,c]
            ieq[r,c] = np.clip(255. * cdf[pixelvalue], 0, 255).astype (np.uint8)
    #
    return ieq
#

# do it now
img_eq = histogram_equalization (img, cdf)

plt.imshow (img_eq, cmap='gray'); plt.title('histogram equalized')
plt.pause(1)
plt.close()

# check the histogram of the equalized image.
# verify what you did.

heq = histogram (img_eq)
```

```
plt.bar (range(0,256), heq, width=4)
plt.title('histogram of histogram-equalized image')
plt.pause (1)
plt.close()

# Now, make & plot the CDF of heq


# EOF
```

Q. For an RGB image, convert it to HSV format, apply hisotgram equalization to V channel, convert back to RGB. Show an example.

Chapter 6

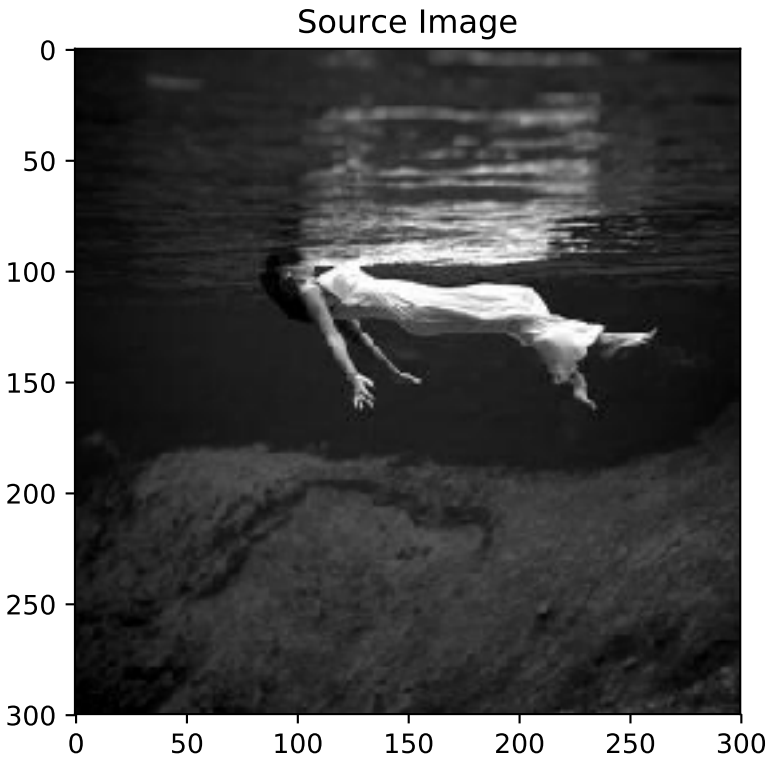
Gamma Correction

- Read Wikipedia Gamma Correction Page

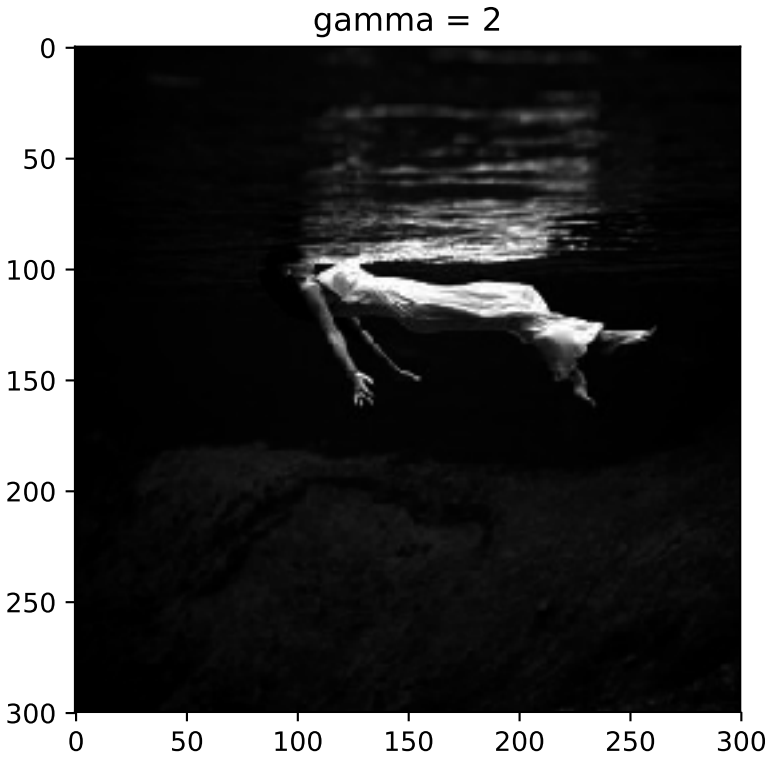
```
# filename gamma_correction.py
# https://en.wikipedia.org/wiki/Gamma_correction
# The image used from wikipedia seems to be from https://www.art.com/gallery/id--c23951/black-and-white

import sys
import numpy as np
import cv2
import matplotlib
matplotlib.use ('TkAgg')
import matplotlib.pyplot as plt
import imageio # this will be used to load an image file
import skimage # rgb <-> hsv conversion in [0,1] pixel scale

# show the image
def imshow (img, title=None):
    if img.ndim == 3:
        plt.imshow (img)
    else:
        plt.imshow (img, cmap='gray')

    if title is None: title = 'imshow'
    plt.title (title)
    plt.pause (1)
    plt.close ()
#

img = imageio.imread ('data/art.com.jpg') # it is an RGB format even though ...
if img is None:
    print ('image file open error')
    sys.exit ()
#
print (img.shape)
```

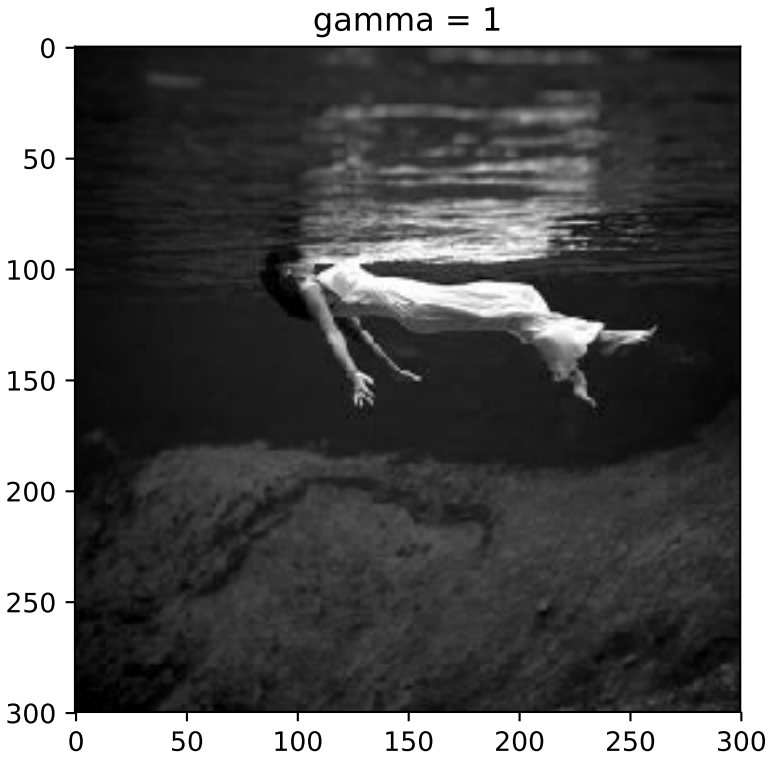
```
## (300, 300, 3)
```

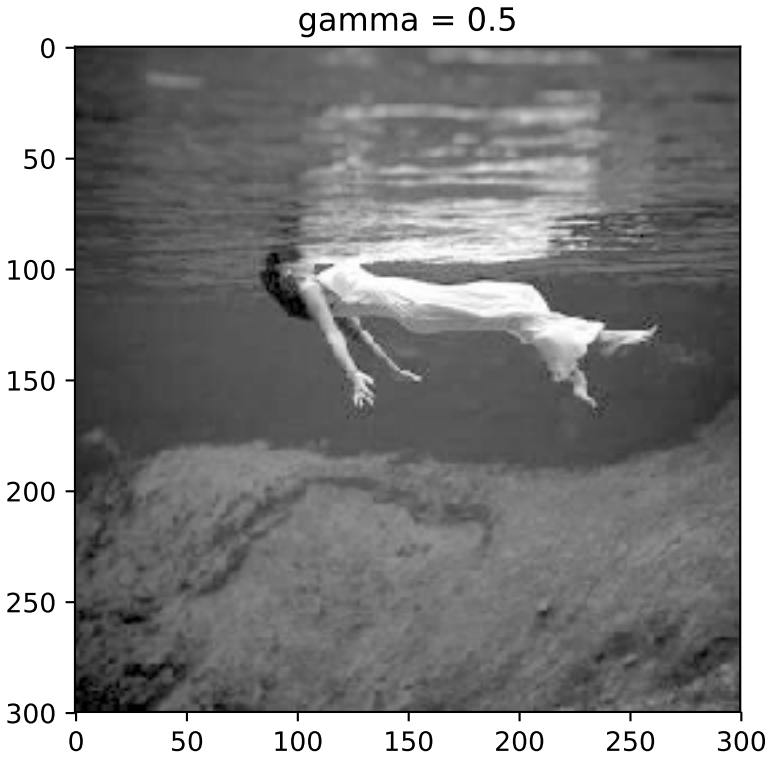
```
imshow (img, 'Source Image')
```

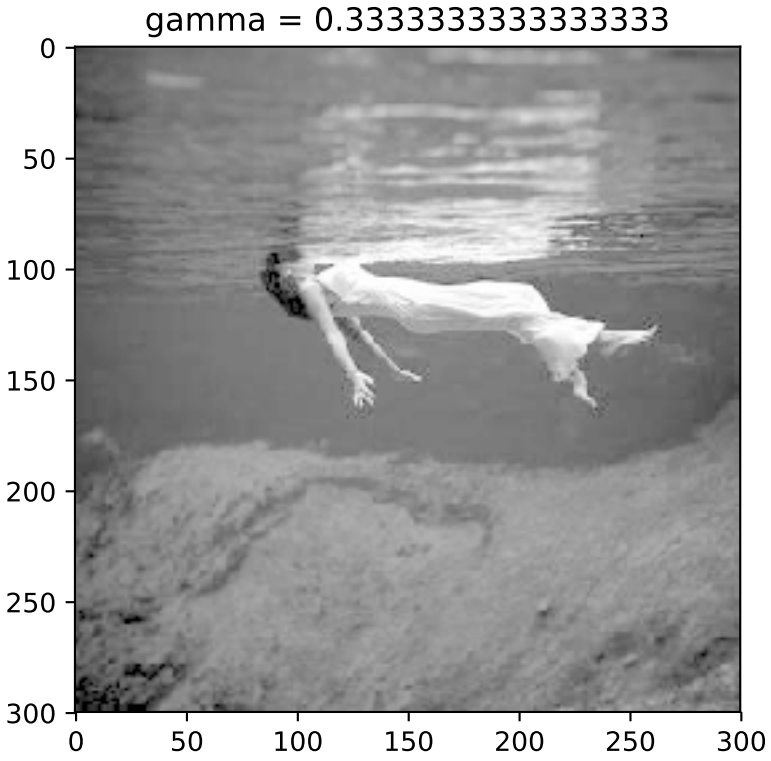


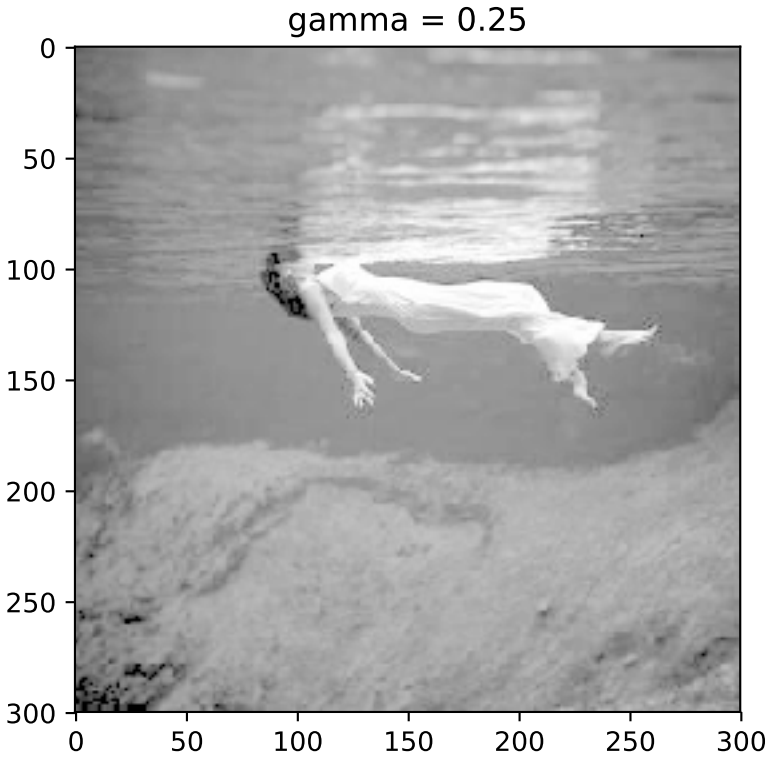

```
gammas = [2, 1, 1./2, 1./3, 1./4]

for gamma in gammas:
    ii = np.power(img/255., gamma)
    imshow (ii, 'gamma = {}'.format(gamma))
#

# Q. Plot histograms

# EOF
```


gamma = 2
0
50
100
150
200
250
300
0
50
100
150
200
250
300


gamma = 1
0
50
100
150
200
250
300
0
50
100
150
200
250
300


gamma = 0.5
0
50
100
150
200
250
300
0
50
100
150
200
250
300


gamma = 0.3333333333333333
0
50
100
150
200
250
300
0
50
100
150
200
250
300


gamma = 0.25
0
50
100
150
200
250
300
0
50
100
150
200
250
300

Chapter 7

HSV Color Space

HSV color representation is another popular way.

```
# filename: rgb_hsv.py
# REF: http://scikit-image.org/docs/dev/auto_examples/color_exposure/plot_rgb_to_hsv.html

# RGB -> HSV is done with skimage.color.rgb2hsv()
#    * RGB, HSV data are assumed to be in the ranage [0,1]

import sys
import numpy as np
import cv2
import matplotlib
matplotlib.use ('TkAgg')
import matplotlib.pyplot as plt
import imageio # this will be used to load an image file
import skimage # rgb <-> hsv conversion in [0,1] pixel scale

# show the image
def imshow (img, title=None):
    if img.ndim == 3:
        plt.imshow (img)
    else:
        plt.imshow (img, cmap='gray')

    if title is None: title = 'imshow'
    plt.title (title)
    plt.pause (1)
    plt.close ()
#

rgb = imageio.imread ('data/nature.jpg') #https://wallpapercave.com/pretty-nature-wallpapers
if rgb is None:
    print ('image file open error')
    sys.exit ()
#

imshow (rgb, 'RGB Image')
```

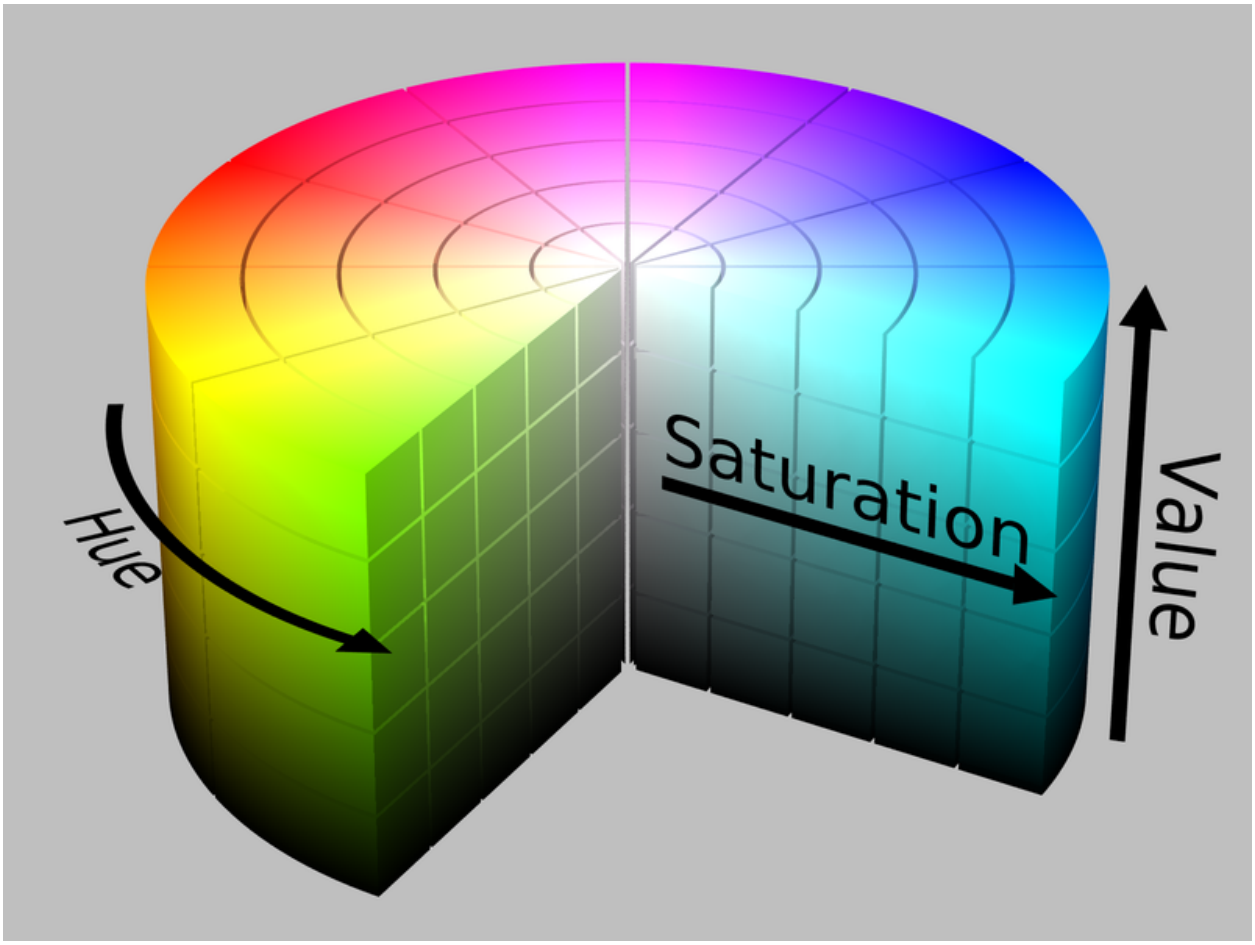
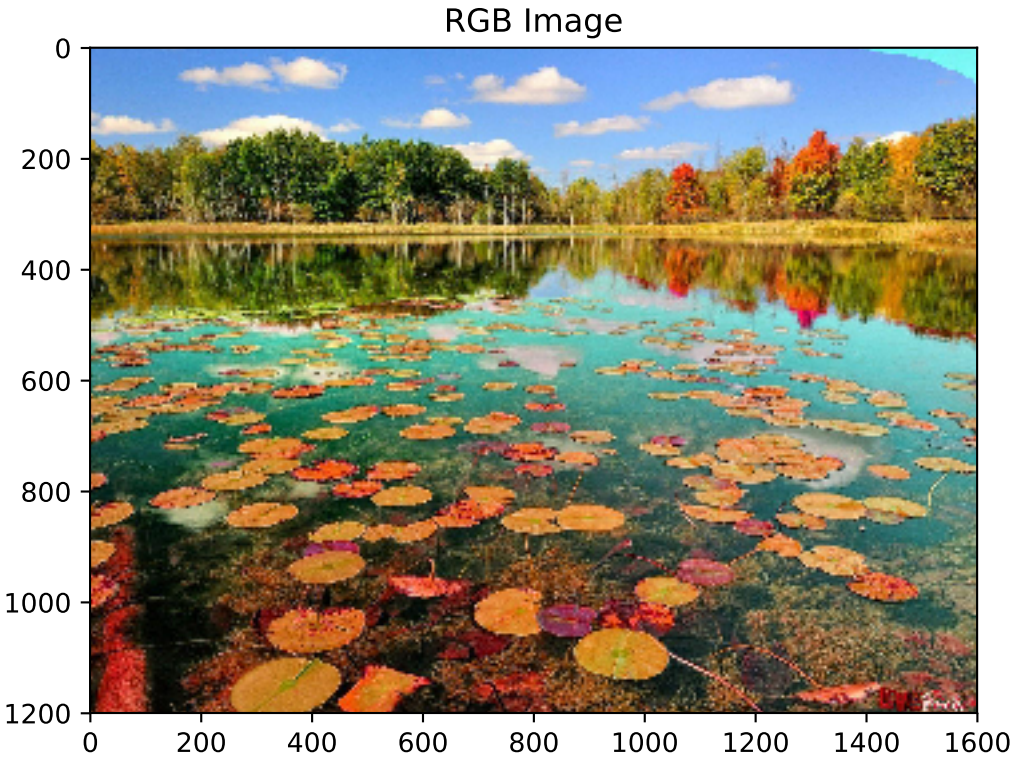
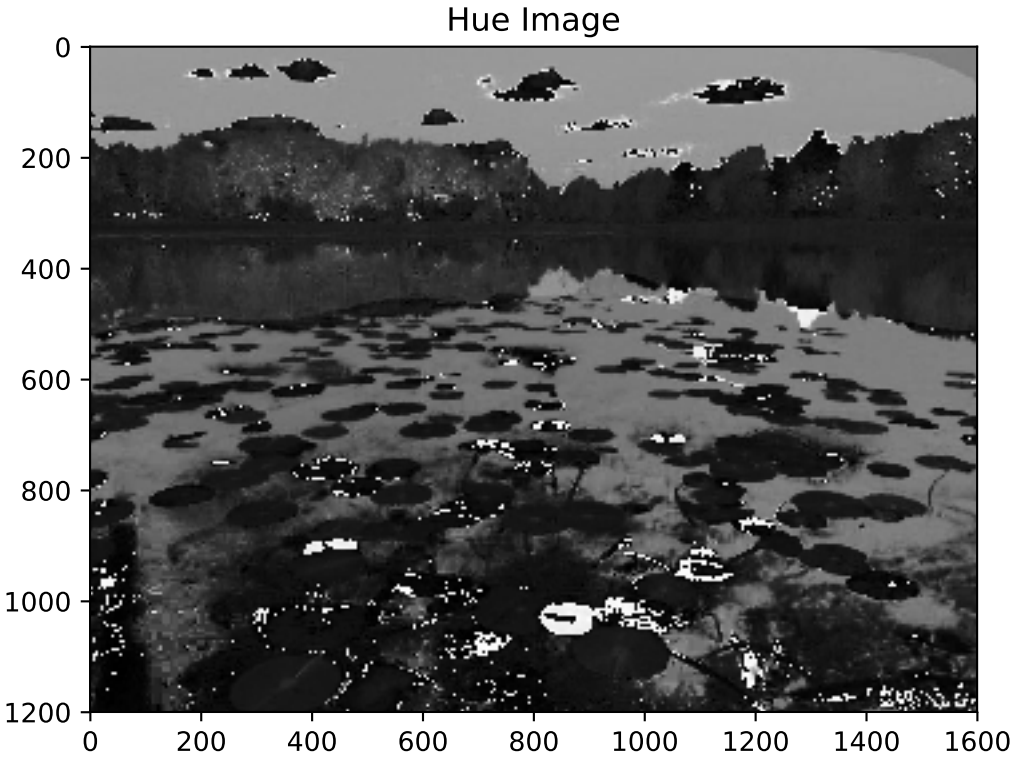


Figure 7.1: HSV Cylinder

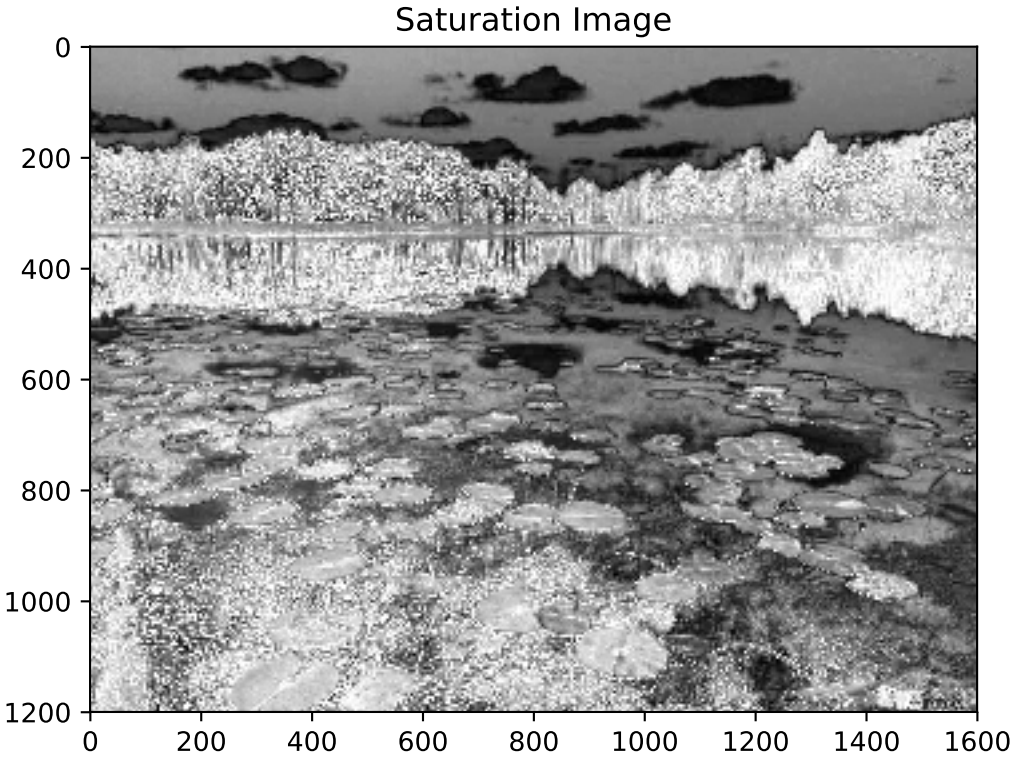
```
# The conversion assumes an input data range of [0, 1] for all color components.
```



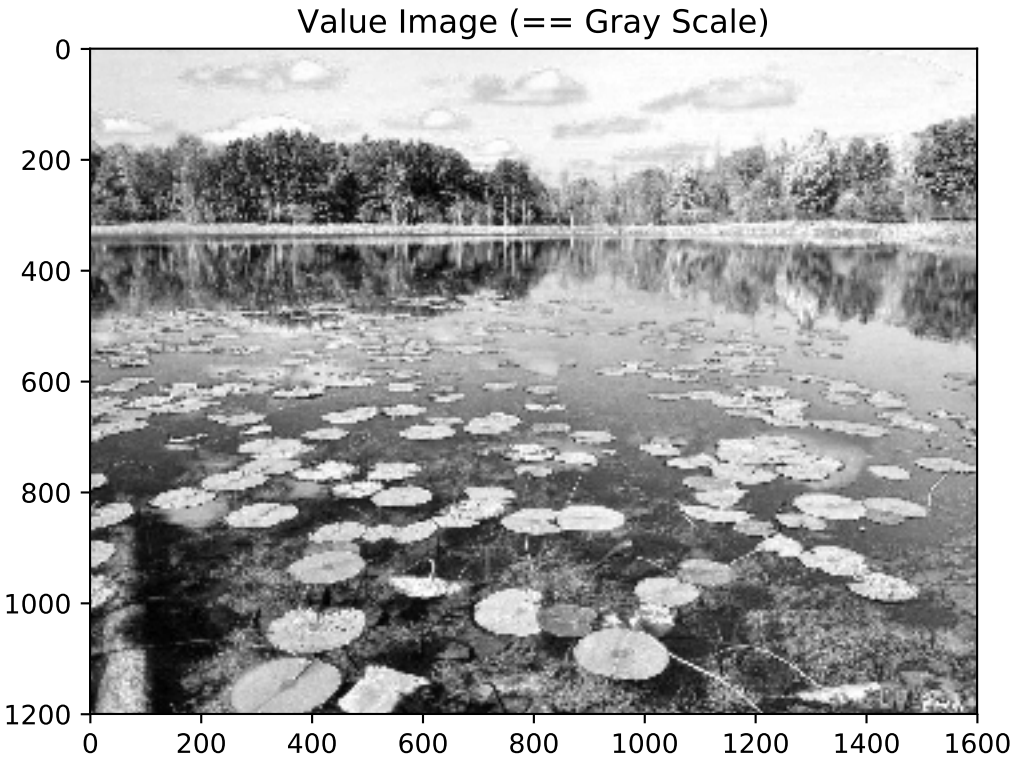

```
rgb01 = rgb/255.
hsv = skimage.color.rgb2hsv (rgb01)
hue = hsv[:,:,0]
saturation = hsv[:,:,1]
value = hsv[:,:,2]

imshow (hue, 'Hue Image')
```




```
imshow (saturation, 'Saturation Image')
```




```
imshow (value, 'Value Image (== Gray Scale)')
```




```
print ('HSV(Red)    = {}'.format(skimage.color.rgb2hsv([[[1.,0,0]]])))
```

```
## HSV(Red)    = [[[0. 1. 1.]]]
```

```
print ('HSV(Yellow)= {}'.format(skimage.color.rgb2hsv([[[1.,1.,0]]])))
```

```
## HSV(Yellow)= [[[0.16666667 1.         1.        ]]]
```

```
print ('HSV(Green) = {}'.format(skimage.color.rgb2hsv([[[0,1.,0]]])))
```

```
## HSV(Green) = [[[0.33333333 1.         1.        ]]]
```

```
print ('HSV(Blue)  = {}'.format(skimage.color.rgb2hsv([[[0,0,1.]]])))
```

```
## HSV(Blue)  = [[[0.66666667 1.         1.        ]]]
```

```
print ('HSV(White) = {}'.format(skimage.color.rgb2hsv([[[1.,1.,1.]]])))
```

```
## HSV(White) = [[[0. 0. 1.]]]
```

```
hsvpixel = [[[0.999, 1., 1.]]]
print ('RGB({}) = '.format(hsvpixel), skimage.color.hsv2rgb (np.array(hsvpixel)))
```

```
## RGB([[[0.999, 1.0, 1.0]]]) =  [[[1.    0.    0.006]]]
```

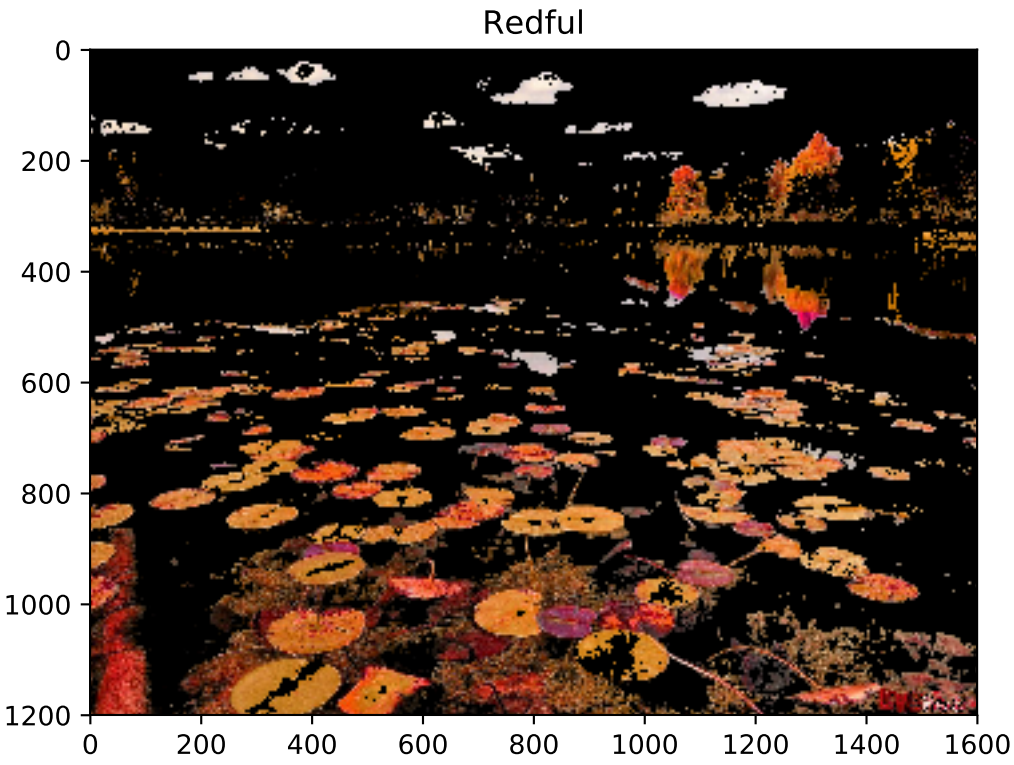
```
hsvpixel = [[[0., 1., 1.]]]
print ('RGB({}) = '.format(hsvpixel), skimage.color.hsv2rgb (np.array(hsvpixel)))
```

```
## RGB([[[0.0, 1.0, 1.0]]]) =  [[[1. 0. 0.]]]
```

```
print ('Now Extract Redful pixels only.')
```

```
## Now Extract Redful pixels only.
```

```
for r in range(hsv.shape[0]):
    for c in range (hsv.shape[1]):
        if (hsv[r,c,0] > 0.9 or hsv[r,c,0] < 0.1):
            pass # this is a red
        else:
            hsv[r,c,:] = [0,0,0] # black
#
rgb_redful = skimage.color.hsv2rgb (hsv)
imshow (rgb_redful, 'Redful')
```



```
imageio.imwrite ('data/redful.png', (rgb_redful*255).astype(np.uint8))

# Q. Can you remove white pixels in the clouds?
#    Hint: Examine the HSV Cylinder. ( hsv[r,c,1] > 0.5 )

# Q. Rotate the color along the HUE axis, make a video of the chage.
#    Step = 0, 0.01, 1

# EOF
```

Chapter 8

Video File Manipulation

8.1 Video File Read/Write

```
# filename: video-open.py
# https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_gui/py_drawing_functions/py_d

import numpy as np
import cv2

video_file = 'data/avideo.mov'
cap = cv2.VideoCapture(video_file)

if cap.isOpened() is False:
    print ('video file open error: ', video_file)
#
width = cap.get (cv2.CAP_PROP_FRAME_WIDTH)
height = cap.get (cv2.CAP_PROP_FRAME_HEIGHT)
nframes = cap.get (cv2.CAP_PROP_FRAME_COUNT)
fps = cap.get (cv2.CAP_PROP_FPS)
print (height, width, nframes, fps)

outvideofile = 'data/outvideo.mov'
out_wh = (640, 480)
outVideo = cv2.VideoWriter (outvideofile, cv2.VideoWriter_fourcc(*'XVID'), 30.0, out_wh)

while(cap.isOpened()):
    ret, frame = cap.read()
    if ret == False:
        break

    frame = cv2.resize(frame, dsize=out_wh)

    font = cv2.FONT_HERSHEY_SIMPLEX
    text_xy = (100, 200)
    frame = cv2.putText (frame, 'OpenCV', text_xy, font, 4, (0,255,255), 2, cv2.LINE_AA)

    cv2.imshow('frame', frame)
```

```
    outVideo.write (frame)

    if cv2.waitKey(30) == 27:
        break
#

cap.release()
outVideo.release()

cv2.destroyAllWindows()

# EOF
```

Notes:

1. The color image in opencv is BGR order, not RGB order.
2. `cap.get()` returns `float` numbers, not integer numbers.
3. The video `frame` obtained from `cap.read()` is a `numpy` array, in BGR order. If you want to know its color values at `(x,y)`, then try `frame[y,x]` and you will get the BGR at the location.
4. The fourcc `cv2.VideoWriter_fourcc()` is always confusing. Please search for a concrete explanation on it.
5. There is no way to deal with sound with `OpenCV`. Try another python module such as `moviepy`, see MoviePy for its documentation. Below is an example:

Try:

- Negative Film Effect Operation for a duration of the video
- Gray Scale
- Reversed-mode play

8.2 Video File Set Frame Position

This is a way of getting a video frame at a specifiic frame number.

- `videoCaputre().set(cv2.CAP_PROP_POS_FRAMES, nth_frame)`
- `videoCaputre().set(cv2.CAP_PROP_POS_AVI_RATIO, relative_position_0_to_1)`

```
# filename: video-lastframe.py

import sys
import numpy as np
import cv2

video_file = 'data/avideo.mov'
cap = cv2.VideoCapture(video_file)

if cap.isOpened() is False:
    print ('video file open error: ', video_file)
    sys.exit()
#
```

```
width = cap.get (cv2.CAP_PROP_FRAME_WIDTH)
height = cap.get (cv2.CAP_PROP_FRAME_HEIGHT)
nframes = cap.get (cv2.CAP_PROP_FRAME_COUNT)
fps = cap.get (cv2.CAP_PROP_FPS)
print (height, width, nframes, fps)

for i in range (int(nframes)):
    fcount = nframes - 1 - i
    cap.set (cv2.CAP_PROP_POS_FRAMES, int(nframes-1-i))
    ret, frame = cap.read()
    if frame is None:
        print ('frame None', i)
        continue
    if ret == False:
        print ('ret False', i)
        continue
    print ('frame read: ', i)

    frame = cv2.resize(frame, dsize=None, fx=.25, fy=.25)

    cv2.imshow('frame', frame)
    if cv2.waitKey(3) == 27:
        break
#

cap.release()
cv2.destroyAllWindows()
# EOF
```

- See: OpenCV VideoCapture Document for `cv2.CV_CAP_PROP_POS_FRAMES` which sets '0-based index of the frame to be decoded/captured next.'

Chapter 9

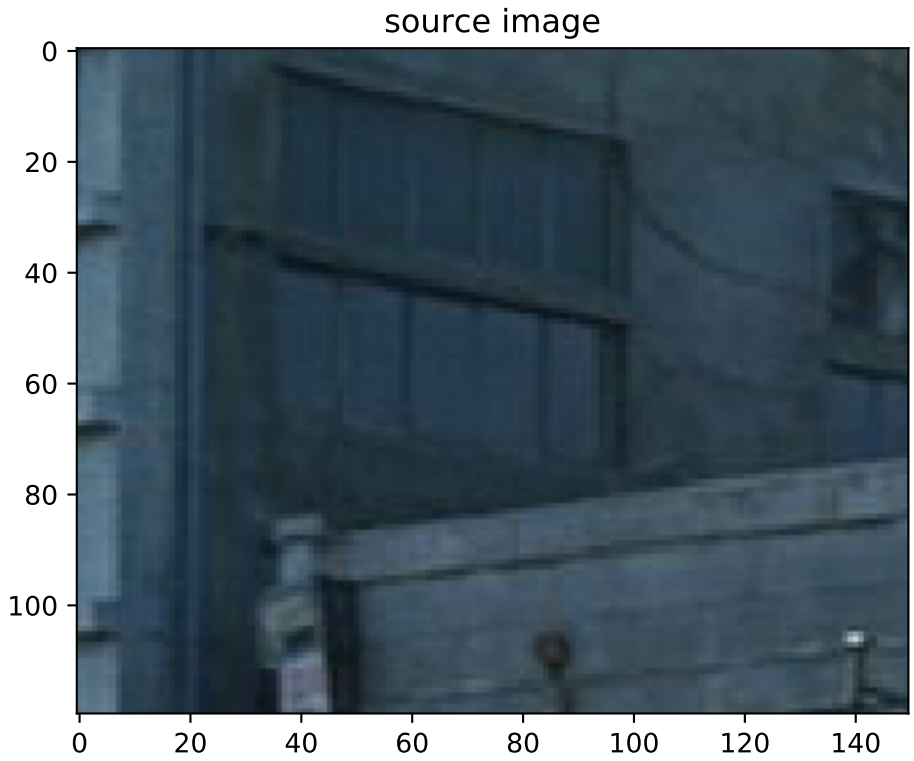
Convolution (Space Filter)

- OpenCV filtering
- Convolution operation: linear filter
- Fast computation should be implemented in C/C++, or use `numpy` with care after its manual.
-

9.1 Smoothing or Blurring

```
# filename: filter-box-blur.py

import time
import numpy as np
import imageio
import skimage
import cv2 # opencv
import matplotlib.pyplot as plt

def imshow (im, title=None, ptime=1):
    if im.ndim == 2:
        plt.imshow (im, cmap='gray')
    elif im.ndim == 3:
        plt.imshow (im)
    else:
        print ('strage image.')
        return
    #
    if title==None: title='image'
    plt.title (title)
    plt.pause(ptime)
    plt.close()
#
def convolution (im, k):
    dst = np.zeros_like (im)
    for d in range (im.shape[2]):
```

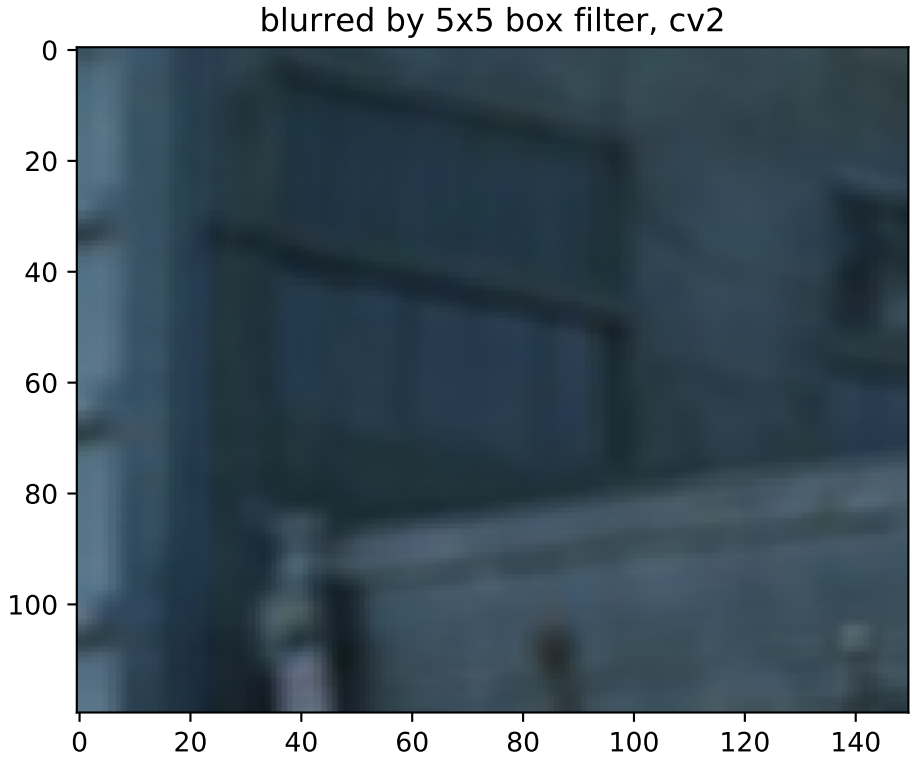
```
        for r in range (im.shape[0] - k.shape[0] + 1):
            for c in range (im.shape[1] - k.shape[1] + 1):
                # convolution = inner product at (r,c,d), pivot is at left-top
                inner = 0.
                for ii in range (k.shape[0]):
                    for jj in range (k.shape[1]):
                        inner +=  im[r+ii, c+jj, d] * k[ii,jj]
                dst[r,c,d] = np.clip(inner+0.5, 0, 255)           # why complicated ?
    #
    return dst
#
im = imageio.imread ('data/img536.jpg')    # read an image file
im = im[:120, 0:150, :]

imshow (im, title='source image')
```




```
kernel = np.ones((5,5), np.float32) / 25.  # filter kernel

t0 = time.time()
blurred = cv2.filter2D (im, -1, kernel)    # filtering
print ('blurred: shape={}, pixel[0,0]={}'.format(blurred.shape, blurred[0,0]), ' %.2f seconds' % (time.t
```

```
## blurred: shape=(120, 150, 3), pixel[0,0]=[58 80 94]  0.01 seconds
```

```
imshow (blurred, 'blurred by 5x5 box filter, cv2')
```



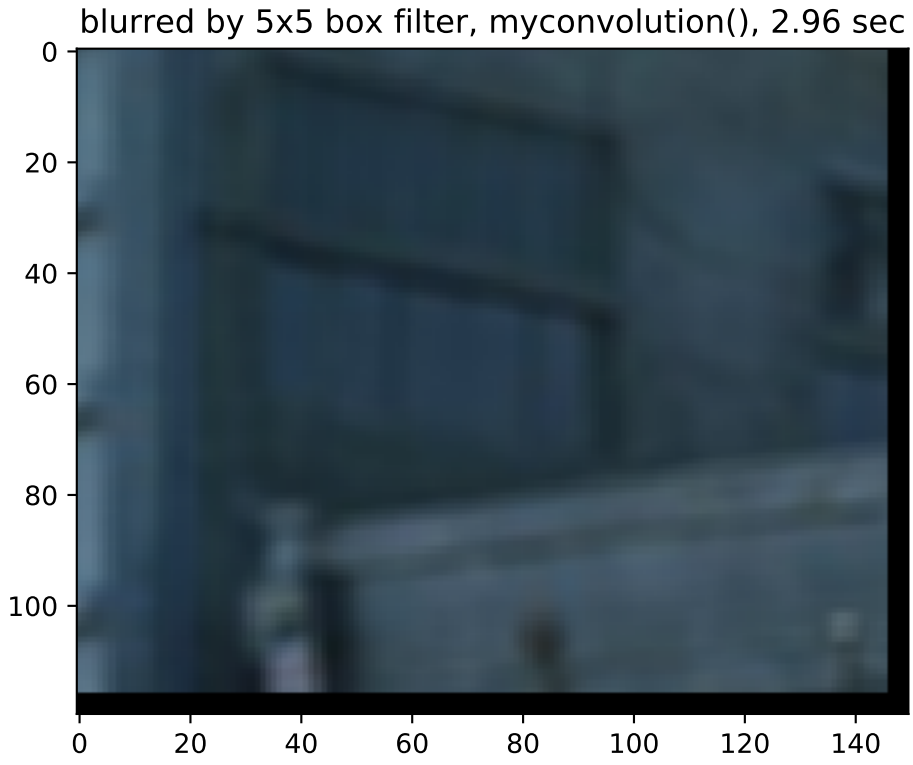

```
print ('Q. How can you produce a motion blurred image?')
```

```
## Q. How can you produce a motion blurred image?
```

```
t0 = time.time()
myblurred = convolution (im, kernel)        # filtering of my own
print ('myblurred: shape={}, pixel[0,0]={}'.format(myblurred.shape, myblurred[0,0]), ' %.2f seconds.'%(
```

```
## myblurred: shape=(120, 150, 3), pixel[0,0]=[ 62  86 100]  2.96 seconds.
```

```
imshow (myblurred, 'blurred by 5x5 box filter, myconvolution(), %.2f sec' % (time.time()-t0))
```

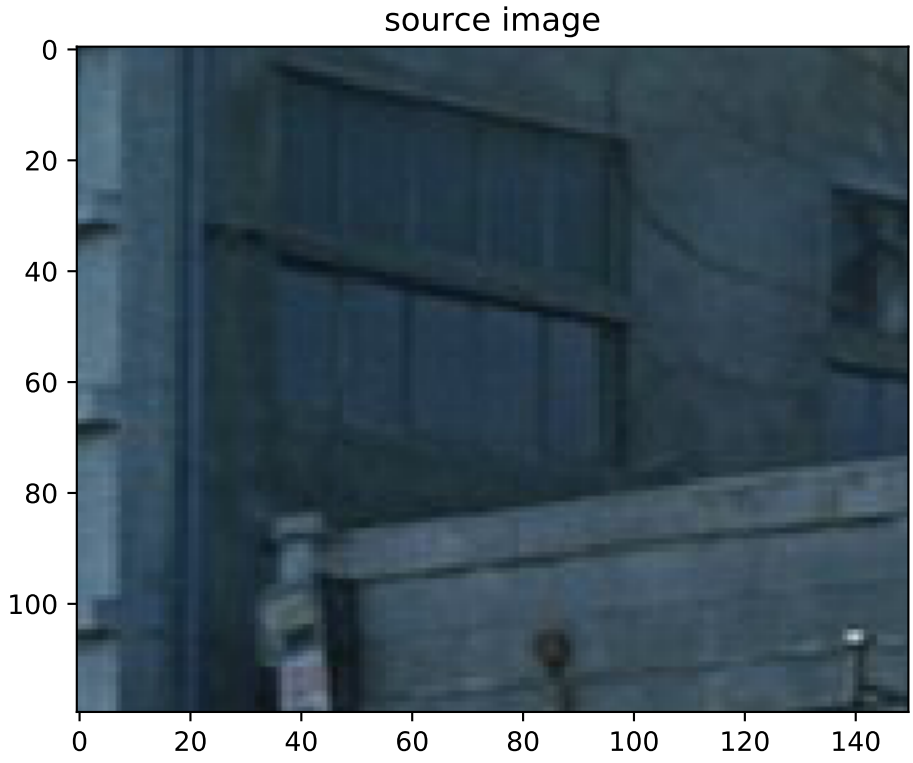



```
print ('Q. Why are the pixel colors different?')

# Gaussian Blurring
```

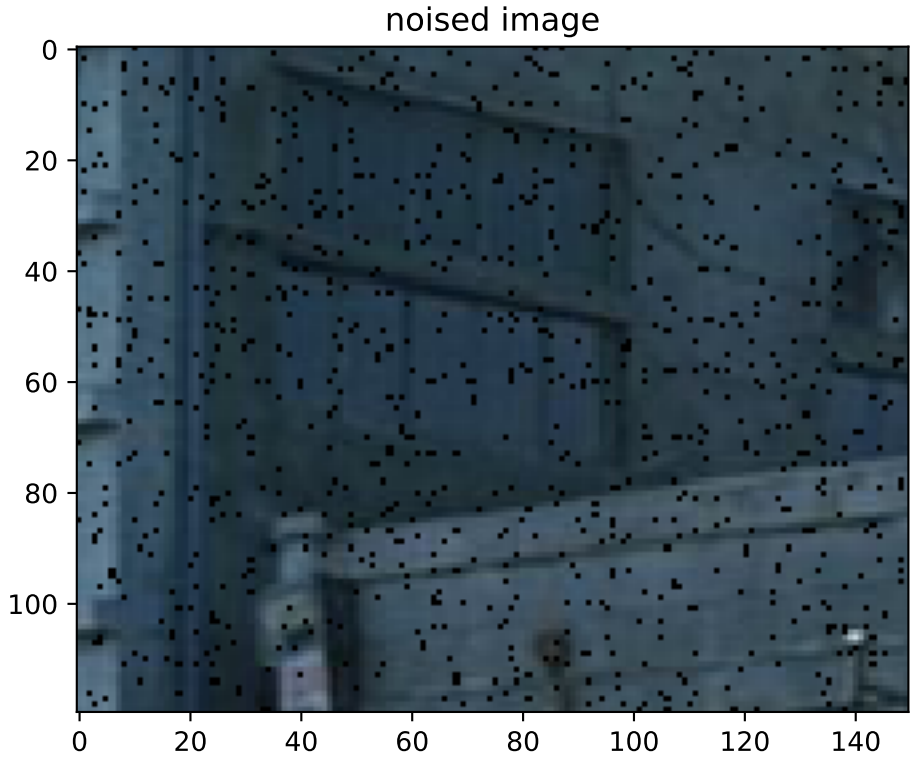
```
## Q. Why are the pixel colors different?
```

```
blurr_g = cv2.GaussianBlur (im, (5,5), 0) # 0 means automatic 5x5 Gaussian kernel
imshow (blurr_g, 'Gaussian blur with 5x5')


# Median blur
```

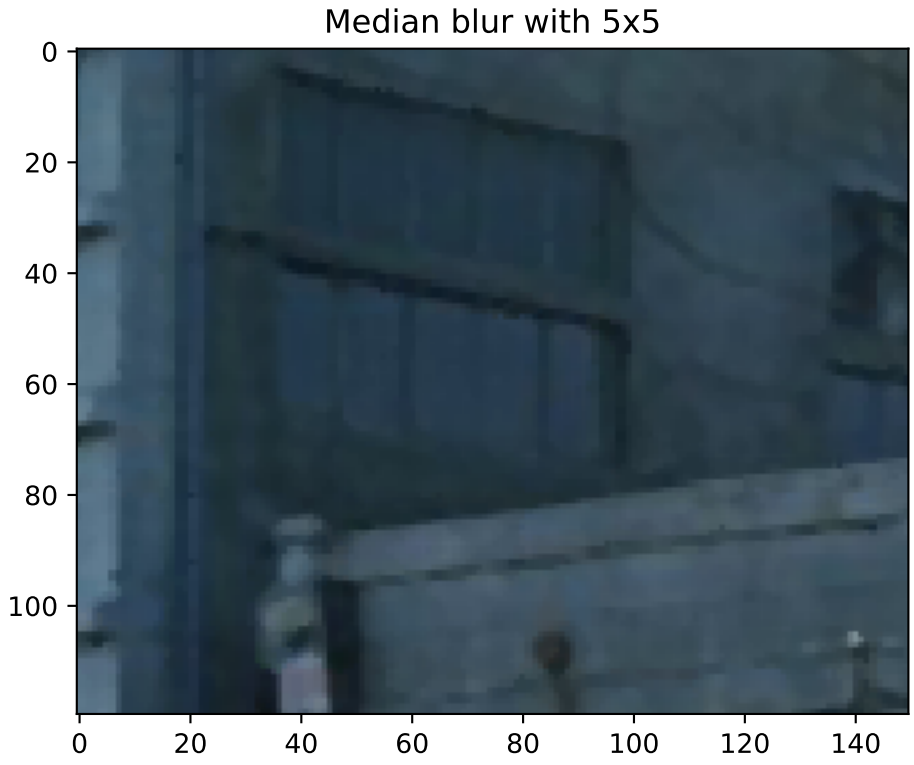

```
im2 = im.copy()
imshow (im2, 'source image')
## speckle noise (black or white)
```




```
for i in range(im.shape[0]*im.shape[1]//10): # 10 % noise
    r = np.random.randint(0, im.shape[0])
    c = np.random.randint(0, im.shape[1])
    if np.random.rand() < 0.5:
        im2[r,c] = 0 # black
    else:
        im[r,c] = 255 # white
#
imshow (im2, 'noised image', ptime=3)
##
```



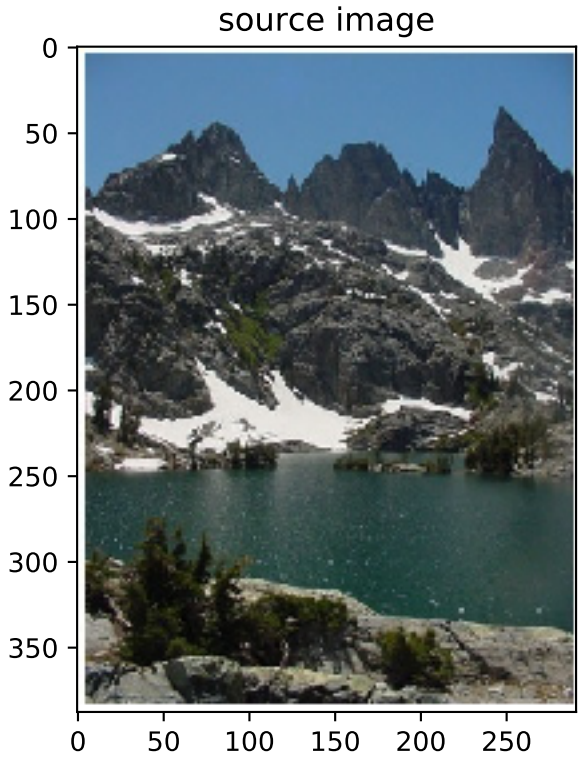

```
median = cv2.medianBlur (im2, 3)
imshow (median, 'Median blur with 5x5')
```



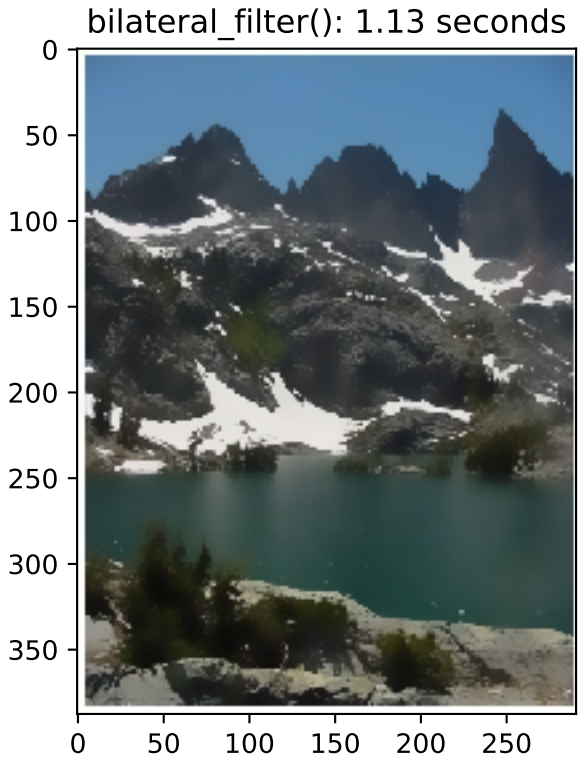

```
print ('Q. Try various sizes and observe differences.')

# Bilateral Filtering
```

```
## Q. Try various sizes and observe differences.
```

```
im = imageio.imread ('data/filter_input.jpg')
t0 = time.time()
bf_out = cv2.bilateralFilter (im, 15, 80, 80)
imshow (im, 'source image')
```




```
imshow (bf_out, 'bilateral_filter(): {:.2f} seconds'.format(time.time()-t0))
```




```
print ('Q. Try other parameters for bilateral Filter.')

# EOF
```

```
## Q. Try other parameters for bilateral Filter.
```

Chapter 10

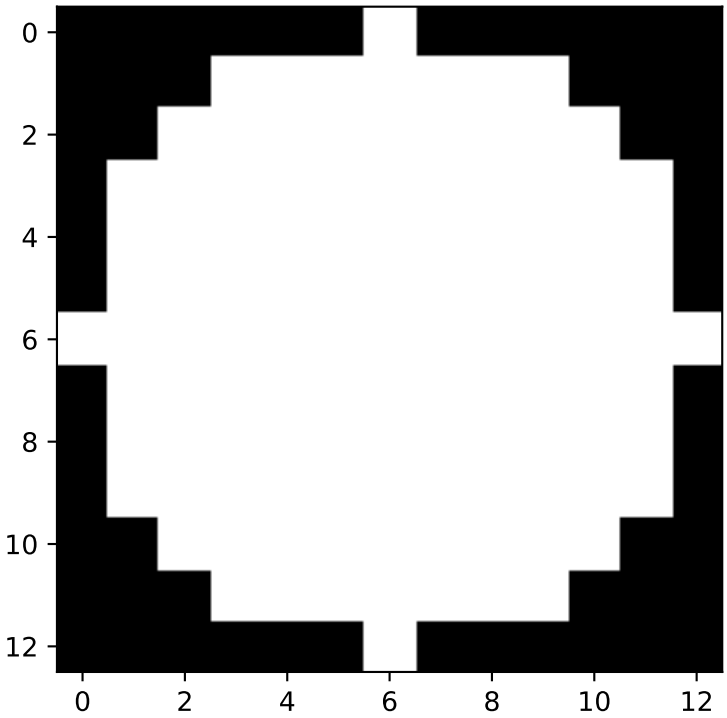
Morphological Filters

- Dilate = choose max
- Erode = choose min
- see skimage examples

```
import os
import imageio
import matplotlib.pyplot as plt
from skimage.morphology import erosion, dilation, opening, closing, white_tophat
from skimage.morphology import black_tophat, skeletonize, convex_hull_image
from skimage.morphology import disk

selem = disk(6)
print (type(selem), selem.dtype, selem.shape, '\n', selem)
```

```
## <class 'numpy.ndarray'> uint8 (13, 13)
##  [[0 0 0 0 0 0 1 0 0 0 0 0 0]
##  [0 0 0 1 1 1 1 1 1 1 0 0 0]
##  [0 0 1 1 1 1 1 1 1 1 1 0 0]
##  [0 1 1 1 1 1 1 1 1 1 1 1 0]
##  [0 1 1 1 1 1 1 1 1 1 1 1 0]
##  [0 1 1 1 1 1 1 1 1 1 1 1 0]
##  [1 1 1 1 1 1 1 1 1 1 1 1 1]
##  [0 1 1 1 1 1 1 1 1 1 1 1 0]
##  [0 1 1 1 1 1 1 1 1 1 1 1 0]
##  [0 1 1 1 1 1 1 1 1 1 1 1 0]
##  [0 0 1 1 1 1 1 1 1 1 1 0 0]
##  [0 0 0 1 1 1 1 1 1 1 0 0 0]
##  [0 0 0 0 0 0 1 0 0 0 0 0 0]]
```

```
plt.imshow (selem, cmap='gray')
plt.pause(2)
```


0
2
4
6
8
10
12
0
2
4
6
8
10
12

Chapter 11

Gradient & Edge Operation

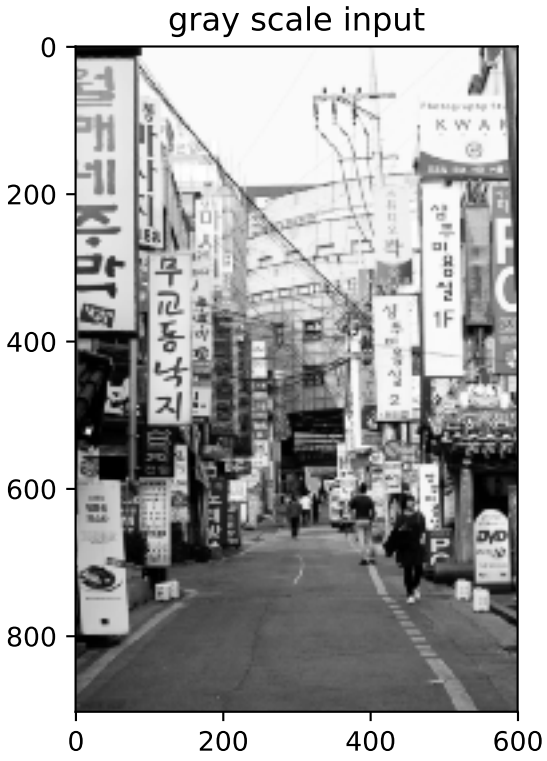
- Check Toturial on Sobel Derivatives
- Linear operators can be exchanged:
- The gradient of $G(\sigma)$ is approximated in discrete space: Sobel, Prewit, etc.
- Edge magnitude:
- Norm (mathematics)
- L0 Norm, L1 Norm, L-Infinity Norm

1. Sobel X, Y
2. Sobel Magnitude & Direction
3. Canny Edge Detector

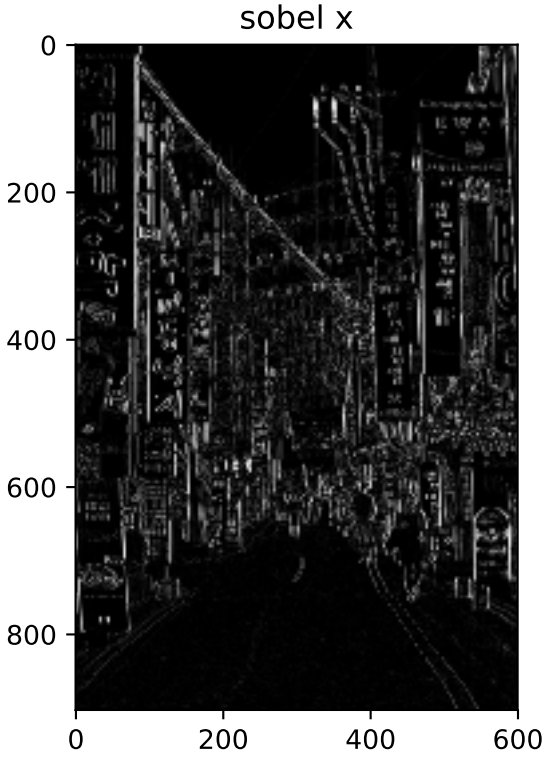
11.1 Sobel-X

```
# filename: sobel-x.py
# ref: https://docs.opencv.org/3.4.3/d2/d2c/tutorial_sobel_derivatives.html

import cv2
import matplotlib
matplotlib.use ('TkAgg') # my linux machine requires this, but your may not!
import matplotlib.pyplot as plt
import imageio
import skimage
import numpy as np

def imshow (gray, title=None):
    plt.imshow (gray, cmap='gray')
    if title == None: title='imshow'
    plt.title(title)
    plt.pause(5); plt.close()
#
```

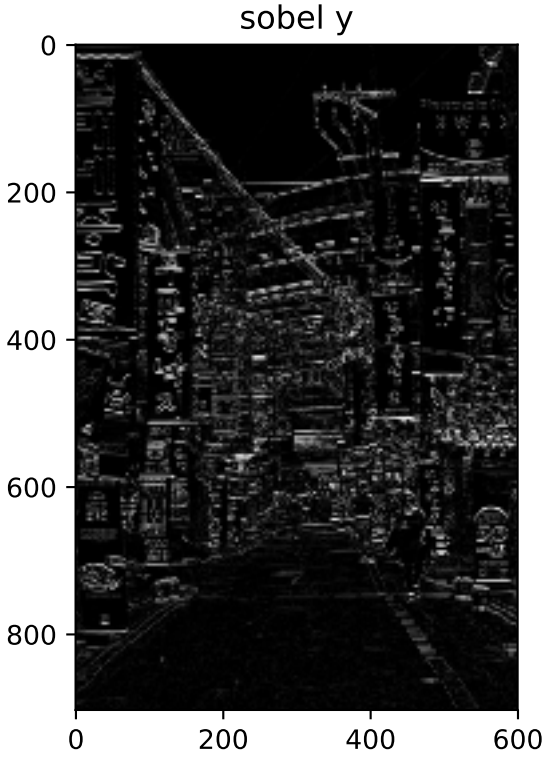
```
src = imageio.imread ('data/imgKorea012.png')
gray = skimage.color.rgb2gray(src)
gray = skimage.filters.gaussian (gray/255., sigma=1)

grad_x = skimage.filters.sobel_v(gray)  # vertical edge comes from x-gradient
grad_y = skimage.filters.sobel_h(gray)  # horizontal edge from y-grad
sobel = skimage.filters.sobel(gray)     # sobel-magnitude

mag = np.sqrt( grad_x**2 + grad_y**2 ) / np.sqrt(2.)

imshow (gray, 'gray scale input')
```



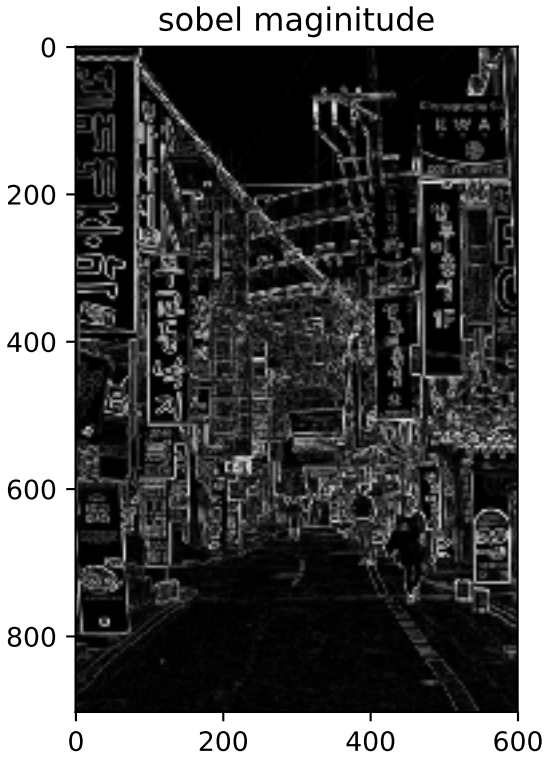

```
imshow (np.abs(grad_x), 'sobel x')
```



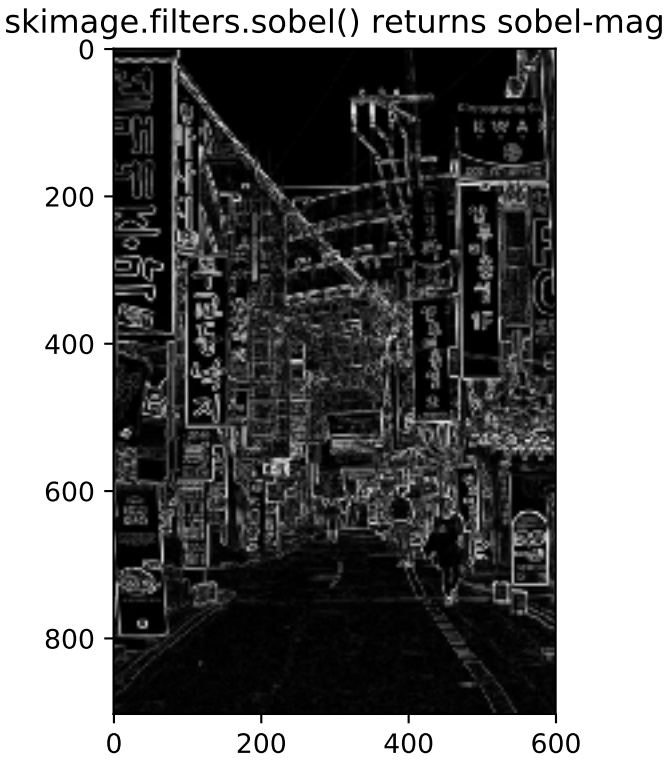

```
imshow (np.abs(grad_y), 'sobel y')
```




```
imshow (mag, 'sobel maginitude')
```




```
imshow (sobel, 'skimage.filters.sobel() returns sobel-mag')

# EOF
```



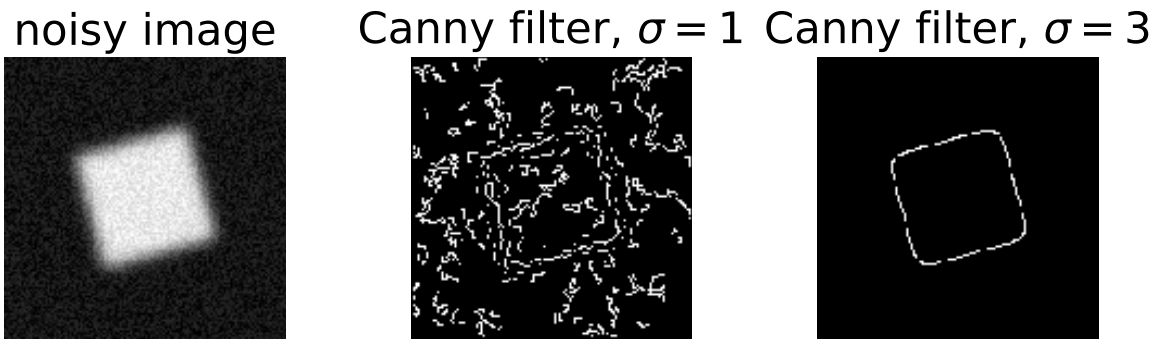
Q. Produce edge-enhanced image using a combination of binarization and sobel edge map.

11.2 Canny Edge Detector

- Edge map is extracted. That is, the output contains 0/1 values only (1 for edge pixels).
- The result depends on the value of `sigma` (σ) that controls the width of Gaussian operator for edge detection.

```
# canny-edge.py
# ref: http://scikit-image.org/docs/dev/auto_examples/edges/plot_canny.html#sphx-glr-auto-examples-edge

import numpy as np
import matplotlib
matplotlib.use ('TkAgg') # my linux machine requires this, but your may not!
import matplotlib.pyplot as plt
from scipy import ndimage as ndi
import imageio
import skimage
from skimage import feature


# Generate noisy image of a square
im = np.zeros((128, 128)) # black image
im[32:-32, 32:-32] = 1 # white square
```

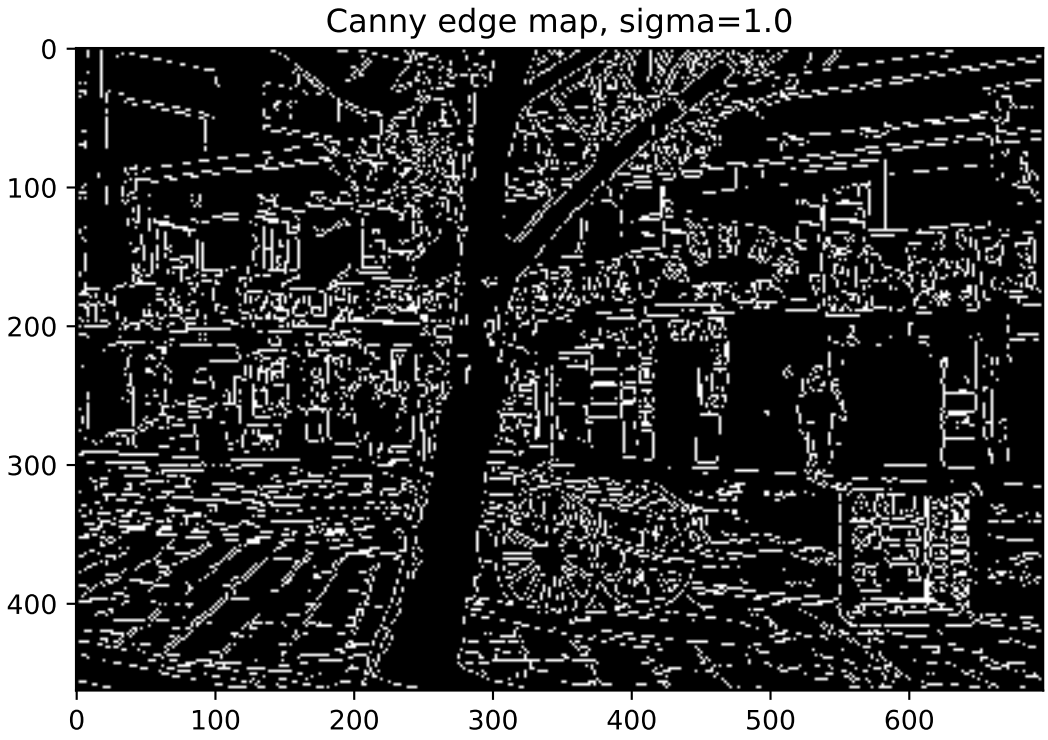
```
im = ndi.rotate(im, 15, mode='constant') # rotate
im = ndi.gaussian_filter(im, 4)          # smoothing/blurring
im += 0.2 * np.random.random(im.shape)   # noise

# Compute the Canny filter for two values of sigma
# output: binary edge map (1: edge pixel, 0: non-edge pixel)
edges1 = feature.canny(im)               # sigma = 1, default
edges2 = feature.canny(im, sigma=3)

# display results
fig, (ax1, ax2, ax3) = plt.subplots(nrows=1, ncols=3,
                                    figsize=(8, 3),
                                    sharex=True, sharey=True)

ax1.imshow(im, cmap=plt.cm.gray)
ax1.axis('off'); ax1.set_title('noisy image', fontsize=20)

ax2.imshow(edges1, cmap=plt.cm.gray)
ax2.axis('off'); ax2.set_title('Canny filter, $\sigma=1$', fontsize=20)

ax3.imshow(edges2, cmap=plt.cm.gray)
ax3.axis('off'); ax3.set_title('Canny filter, $\sigma=3$', fontsize=20)

fig.tight_layout()
plt.pause(1); plt.close()

# Apply Canny to a natural Image
```




```
im = imageio.imread('data/img536.jpg')
gray = skimage.color.rgb2gray (im)
sigma = 1.
edge = skimage.feature.canny(gray, sigma=sigma)
print ('edge: ', edge.shape)
```

```
## edge:  (463, 697)
```

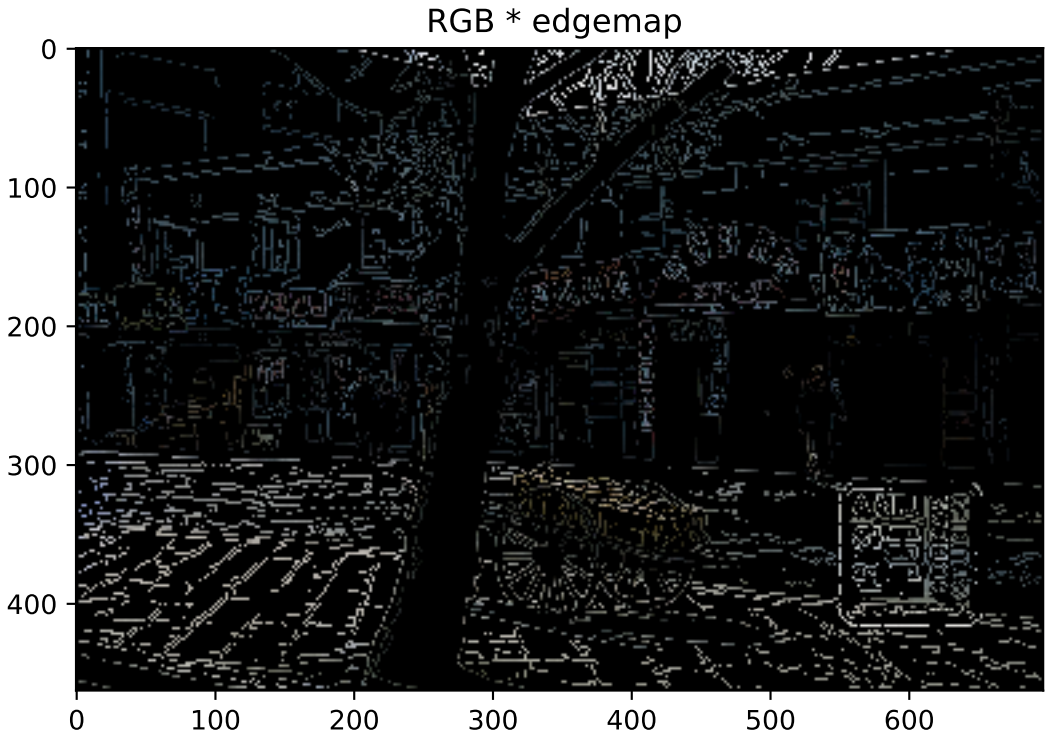
```
plt.imshow (edge, cmap='gray')
plt.title ('Canny edge map, sigma={:.1f}'.format(sigma)); plt.pause(1); plt.close()

# Get edge color, just for displaying
```




```
imedge = im.copy()
for i in range(3):
    imedge[:,:,i] = im[:,:,i] * edge
print (imedge.shape)
```

```
## (463, 697, 3)
```

```
plt.imshow (imedge)
plt.title ('RGB * edgemap '); plt.pause(1); plt.close()

# EOF
```


RGB * edgemap
0
100
200
300
400
0
100
200
300
400
500
600

1. Q. Try various values of `sigma`.
2. Q. Apply morphological operators to the edge map.
3. Q. Try to extract edge's connect data with `cv.findContours()`.

Chapter 12

MoviePy to manipulate movie files

If you need to manipulate audio & video together, `moviepy` is an option.

- Check the site.

```
$ pip3 install moviepy
$ sudo apt-get install imagemagick
```

12.1 Install `youtube-dl`

```
 $ pip install youtube-dl
 $ youtube-dl <youtube.com url>
```

12.2 Text overlay on a video clip

```
# filename: moviepy_textoverlay.py

# ref: https://zulko.github.io/moviepy/getting_started/quick_presentation.html


# Import everything needed to edit video clips
from moviepy.editor import *

# Load a movie file
clip = VideoFileClip("./data/avideo.mov")

# Reduce the audio volume (volume x 0.8)
clip = clip.volumex(0.8)

# Generate a text clip. You can customize the font, color, etc.
txt_clip = TextClip("My Holidays 2013",fontsize=70,color='white')

# Say that you want it to appear at the center of the screen
# The same duration of the video
```

```
txt_clip = txt_clip.set_pos('center').set_duration(clip.duration)

# Overlay the text clip on the first video clip
video = CompositeVideoClip([clip, txt_clip])

# Write the result to a file (many options available !)
# 'mp4' was OK.
# Other extensions caused system error:
# Could not load source '</usr/local/lib/python3.6/site-packages/decorator.py:decorator-gen-49>': Sourc

video.write_videofile("./data/avideo_overlay_text.mp4")

# EOF
```

- Use 'mp4' extension to save to a file (in Linux). No experience with Windows 10 / Mac OS X.

12.3 Extract audio (MP3) from a movie file

```
# filename: moviepy_get_audio.py

from moviepy.editor import *

moviefile = 'data/dooly.mp4'
video = VideoFileClip(moviefile) # open a movie file

audio = video.audio  # get the audio part

audiofile = 'data/dooly_audio_extracted.mp3'
audio.write_audiofile(audiofile) # file save

import os
os.listdir ('data/*.mp3')

# EOF
```

12.4 Movie Concatanation

```
# filename: moviepy_concat.py

from moviepy.editor import VideoFileClip, concatenate_videoclips

clip1 = VideoFileClip("myvideo.mp4")
clip2 = VideoFileClip("myvideo2.mp4").subclip(50,60)
clip3 = VideoFileClip("myvideo3.mp4")

# The result is a concatanaton of the three movie clips.
final_clip = concatenate_videoclips([clip1,clip2,clip3])
```

```
final_clip.write_videofile("my_concatenation.mp4")

# EOF
```

12.5 Apply Filter Frame by Frame

```
# filename: moviepy_filter.py

# https://zulko.github.io/moviepy/getting_started/effects.html

# Import everything needed to edit video clips
from moviepy.editor import *
import cv2

# Load a movie file
clip = VideoFileClip("./data/avideo.mov")

# filter
def myFilter (frame):
    # print (frame.flags) # frame is read-only
    # frame: numpy array (rows, cols, 3) of np.uint8 type
    # print (type(frame), frame.dtype, frame.shape)
    # frame[10:20, 20:30,0] = 0 # frame is read-only
    edited = frame.copy()
    h,w,c = edited.shape
    # apply my own filter, remove red & green color, leave blue
    edited[h//2-100:h//2+100, w//2-50:w//2+50,0:2] = 0

    return edited # return the filtered image
#

# apply filter to every frame
video = clip.fl_image (myFilter)

# save to file
video.write_videofile("./data/avideo_myfilter.mp4")

# EOF
```

12.6 MoviePy Open & Get A Frame

```
#
from moviepy.editor import *
import numpy as np

videofile = 'data/avideo.mov'
movie = VideoFileClip(videofile)
audio = movie.audio
```

```
duration = movie.duration # == audio.duration, presented in seconds, float
#note video.fps != audio.fps
print ('video.duration: {} seconds with fps= {}'.format(movie.duration, movie.fps))
print ('audio.duration: ', audio.duration, audio.fps)

step = 0.1
for t in range(int(duration / step)): # runs through audio/video frames obtaining them by timestamp wit
    t = t * step
    if t > audio.duration or t > movie.duration: break
    audio_frame = audio.get_frame(t) #numpy array representing mono/stereo values
    video_frame = movie.get_frame(t) #numpy array representing RGB/gray frame

    movie.show(t)
#
# EOF
```

12.7 Errors

- Use 'mp4' to save a movie clip into a file! Error:

  ```
  Could not load source '</usr/local/local/lib/python3.6/site-packages/decorator.py:decorator-gen-49>
  ```

- Edit `/etc/ImageMagick-6/policy.xml` : comment out (or remove the line that reads) `<policy domain="path" rights="none" pattern="@*" />`

  ```
  <!-- <policy domain="path" rights="none" pattern="@*" /> -->
  ```

  Error:

  ```
  ImageMagick not detected by moviepy while
  ```

Chapter 13

k-means clustering

```
# filename: kmeans-colors.py
# yndk@sogang.ac.kr
# ref: https://scikit-learn.org/stable/auto_examples/cluster/plot_color_quantization.html

import collections
import numpy as np
import matplotlib.pyplot as plt
import skimage
from sklearn.cluster import KMeans
from time import time

# Load the Summer Palace photo
china = skimage.io.imread ('data/nature-500x375.jpg')
china = china.astype(np.float32) / 255

# Load Image and transform to a 2D numpy array.
assert china.shape[2] == 3 # Color image only
image_array = china.reshape(-1, 3)
print ('image_array_shape = ', image_array.shape)

# Count the number of distinct colors
```

```
## image_array_shape =  (187500, 3)
```

```
colorlist = []
for c in image_array:
    colorlist.append ( (c[0], c[1], c[2]) )
pixelCounter = collections.Counter (colorlist)
n_src_colors = len(pixelCounter)
print ('The number of distinct colors in src image: ', n_src_colors)
```

```
## The number of distinct colors in src image:  139038
```

```
mostCommon10 = pixelCounter.most_common(10)
print ('The most frequent color is {}'.format(mostCommon10[0][0]))
```

```
## The most frequent color is (0.53333336, 0.74509805, 0.9882353)
```

```
plt.imshow(china)
plt.axis('off'); plt.title('Original image ({}) colors'.format(n_src_colors))
plt.pause(1); plt.close()

# Apply kmeans clustering
```


```
print("Perform k-means clustering on {} pixels ... ".format(china.shape[0]*china.shape[1]), end=' ')
```

```
## Perform k-means clustering on 187500 pixels ...
```

```
t0 = time()
n_colors = 10 # the num. of clusters
kmeans = KMeans(n_clusters=n_colors, random_state=0).fit(image_array)
print ('done in %0.3f seconds.' % (time() - t0))

# labels is the array of index labels to cluster center
```

```
## done in 4.634 seconds.
```

```
labels = kmeans.predict(image_array)
print ('labels ({}) = {}'.format(type(labels), labels))
```

```
## labels (<class 'numpy.ndarray'>) = [2 2 2 ... 1 5 5]
```

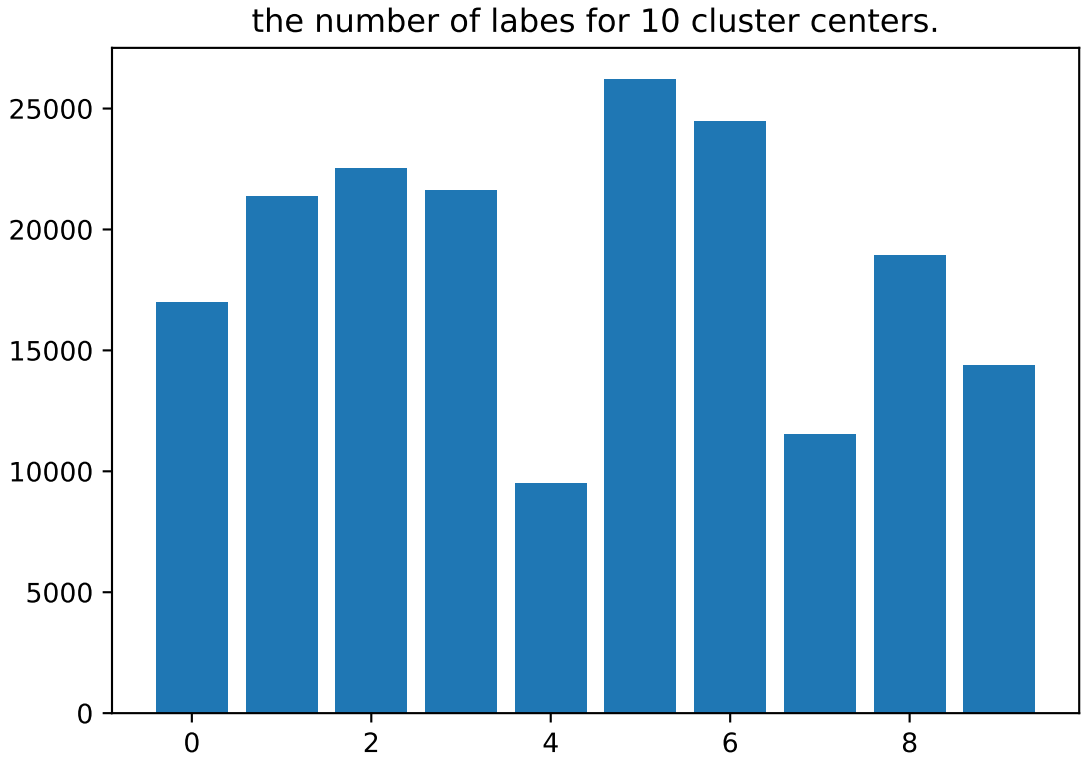
```
labelsCounter = collections.Counter (labels)

maxLabel = labelsCounter.most_common()
print ('The label of maximum population: ', maxLabel)
```

```
## The label of maximum population:  [(5, 26199), (6, 24471), (2, 22540), (3, 21613), (1, 21359), (8, 18
```

```
plt.bar (labelsCounter.keys(), labelsCounter.values())
```

```
## <BarContainer object of 10 artists>
```

```
plt.title ('the number of labes for {} cluster centers.'.format(n_colors))
plt.pause(1); plt.close()
```




```
print ('cluster_centers: \n', kmeans.cluster_centers_)
```

```
## cluster_centers:
##  [[0.24919401 0.3565876  0.27463475]
##  [0.1416738  0.14651027 0.08169898]
##  [0.47987813 0.69187105 0.9496904 ]
##  [0.80619204 0.4875915  0.19484363]
```

```
##  [0.8101161  0.8147739  0.8102013 ]
##  [0.5437143  0.437585   0.22539864]
##  [0.39749712 0.2721435  0.12271127]
##  [0.49875775 0.7651623  0.7272209 ]
##  [0.78249586 0.6431192  0.41146764]
##  [0.36237583 0.5783887  0.50040054]]
```

```
print ('The most common color is ', kmeans.cluster_centers_[maxLabel[0][0]])
```

```
## The most common color is  [0.5437143  0.437585   0.22539864]
```

```
def recreate_image(codebook, labels, ishape):
    """Recreate the (compressed) image from the code book & labels"""
    image = np.zeros(ishape)
    label_idx = 0
    for i in range(ishape[0]):
        for j in range(ishape[1]):
            image[i][j] = codebook[labels[label_idx]]
            label_idx += 1
    return image

plt.imshow(recreate_image(kmeans.cluster_centers_, labels, china.shape))
plt.title('Quantized image ({}) colors by K-Means'.format(n_colors)); plt.axis('off')
```

```
## Text(0.5, 1.0, 'Quantized image (10) colors by K-Means')
## (-0.5, 499.5, 374.5, -0.5)
```

```
plt.pause(1); plt.close()


# Apply kmeans clustering for k=2
```

Quantized image (10) colors by K-Means

```
print("Perform k-means clustering on {} pixels ... ".format(china.shape[0]*china.shape[1]), end=' ')
```

```
## Perform k-means clustering on 187500 pixels ...
```

```
t0 = time()
n_colors = 2 # the num. of clusters
kmeans = KMeans(n_clusters=n_colors, random_state=0).fit(image_array)
print ('done in %0.3f seconds.' % (time() - t0))

# labels is the array of index labels to cluster center
```

```
## done in 0.467 seconds.
```

```
labels = kmeans.predict(image_array)
print ('labels ({}) = {}'.format(type(labels), labels))
```

```
## labels (<class 'numpy.ndarray'>) = [1 1 1 ... 0 0 0]
```

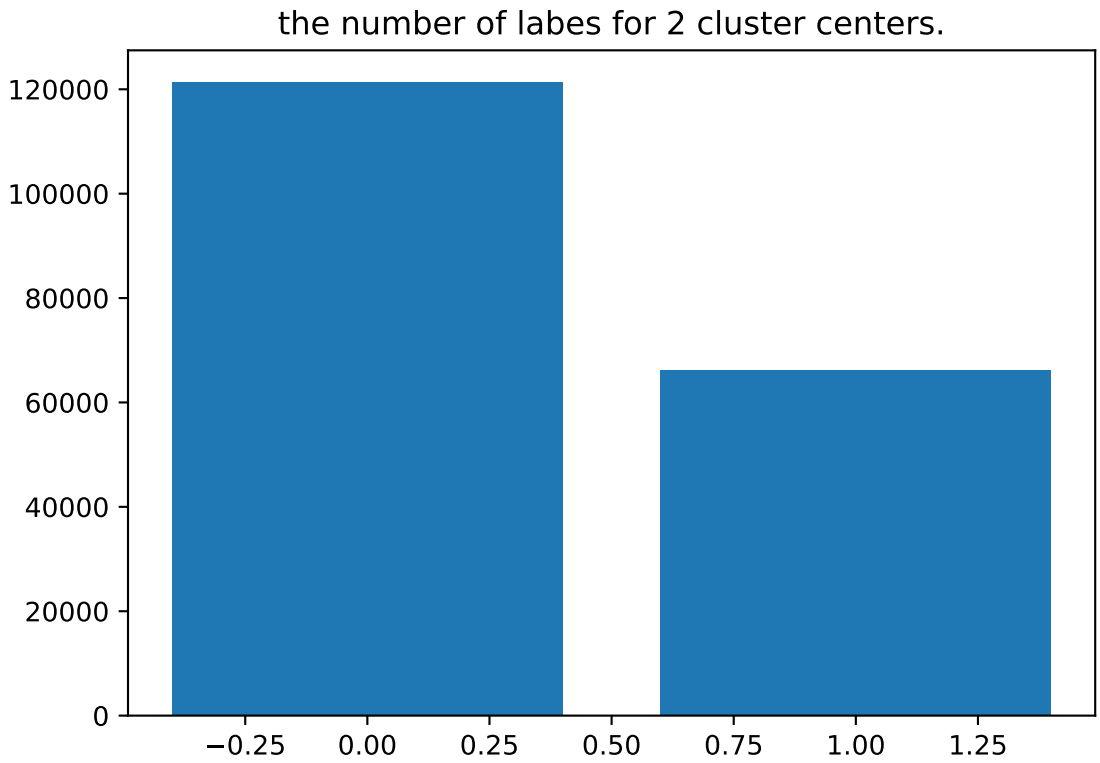
```
labelsCounter = collections.Counter (labels)

maxLabel = labelsCounter.most_common()
print ('The label of maximum population: ', maxLabel)
```

```
## The label of maximum population:  [(0, 121393), (1, 66107)]
```

```
plt.bar (labelsCounter.keys(), labelsCounter.values())
```

```
## <BarContainer object of 2 artists>
```

```
plt.title ('the number of labes for {} cluster centers.'.format(n_colors))
plt.pause(1); plt.close()
```




```
print ('cluster_centers: \n', kmeans.cluster_centers_)
```

```
## cluster_centers:
##  [[0.44632792 0.36047846 0.19587587]
##  [0.58648443 0.70717937 0.72987974]]
```

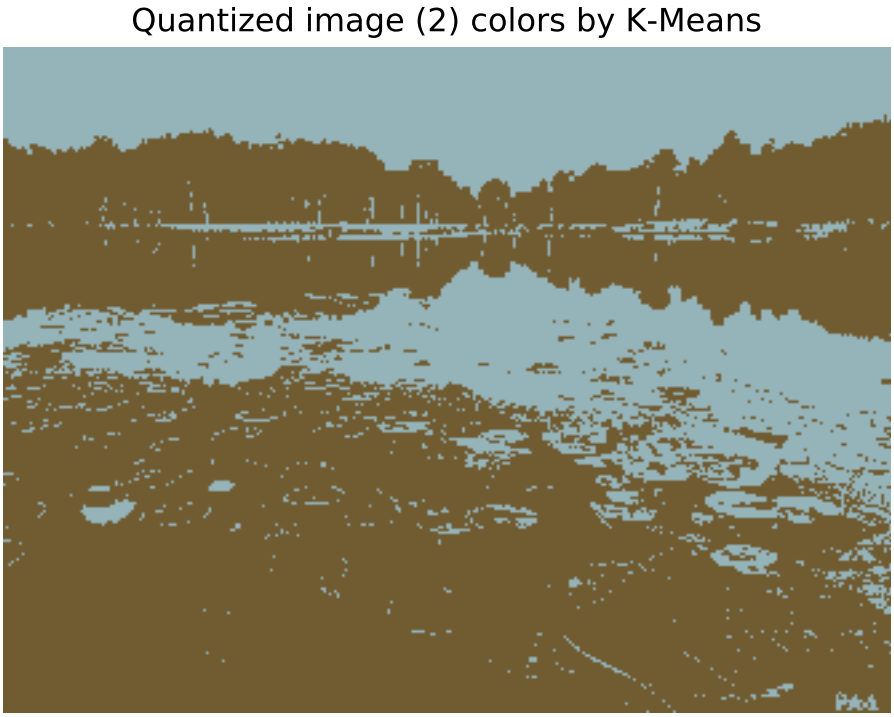
```
print ('The most common color is ', kmeans.cluster_centers_[maxLabel[0][0]])
```

```
## The most common color is  [0.44632792 0.36047846 0.19587587]
```

```
plt.imshow(recreate_image(kmeans.cluster_centers_, labels, china.shape))
plt.title('Quantized image ({}) colors by K-Means'.format(n_colors)); plt.axis('off')
```

```
## Text(0.5, 1.0, 'Quantized image (2) colors by K-Means')
## (-0.5, 499.5, 374.5, -0.5)
```

```
plt.pause(1); plt.close()

# remove or change `random_state=0` & try the program again
# Its purpose is to get an identical result from KMeans procedure.
# You should remove it in practice.
```



Chapter 14

EOF

Chapter 15

SuperPixel Segmentation

- Check Labeling superpixel colorfulness

Chapter 16

Non-Photorealistic Rendering

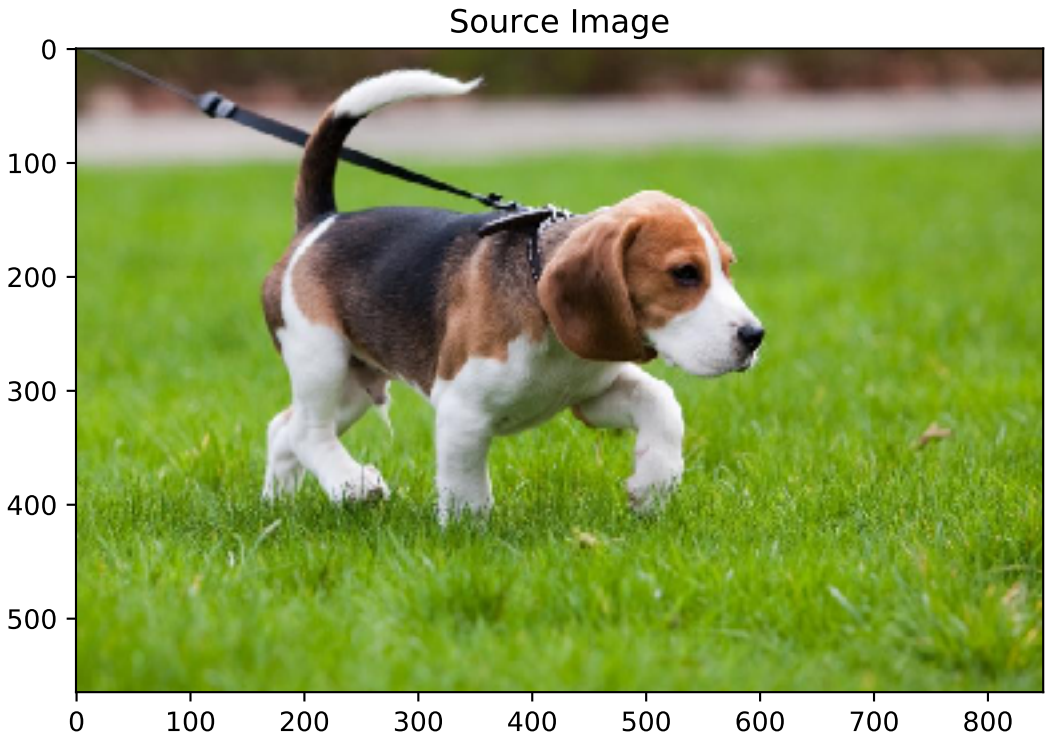
16.1 OpenCV non-photorealistic rendering

- Domain Transform for Edge-Aware Image & Video Processing

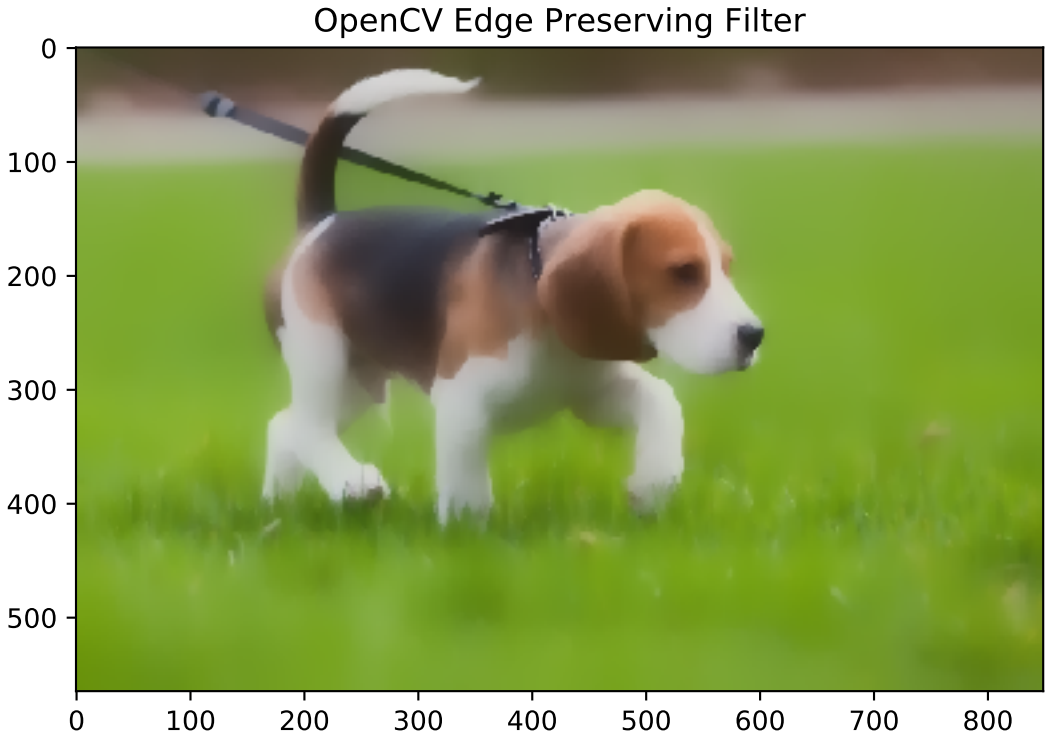
```
# filename: non-photorealistic.py

# https://www.learnopencv.com/non-photorealistic-rendering-using-opencv-python-c/
# https://docs.opencv.org/trunk/df/dac/group__photo__render.html

import sys
import numpy as np
import cv2
import matplotlib
matplotlib.use ('TkAgg')
import matplotlib.pyplot as plt
import imageio # this will be used to load an image file
import skimage # rgb <-> hsv conversion in [0,1] pixel scale

# show the image
def imshow (img, title=None):
    if img.ndim == 3:
        plt.imshow (img)
    else:
        plt.imshow (img, cmap='gray')

    if title is None: title = 'imshow'
    plt.title (title)
    plt.pause (1)
    plt.close ()
#

src = imageio.imread ('data/petinsider.com.jpg') # it is an RGB format even though ...
if src is None:
    print ('image file open error')
    sys.exit ()
#
print (src.shape)
```

```
## (565, 849, 3)
```

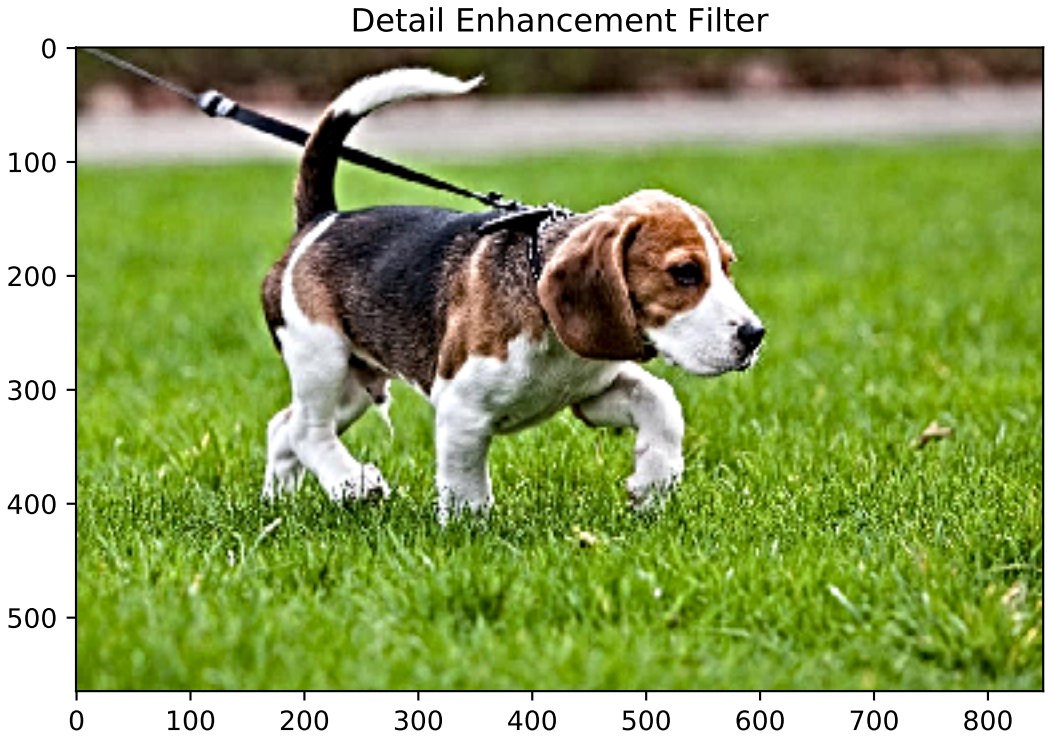
```
imshow (src, 'Source Image')
```



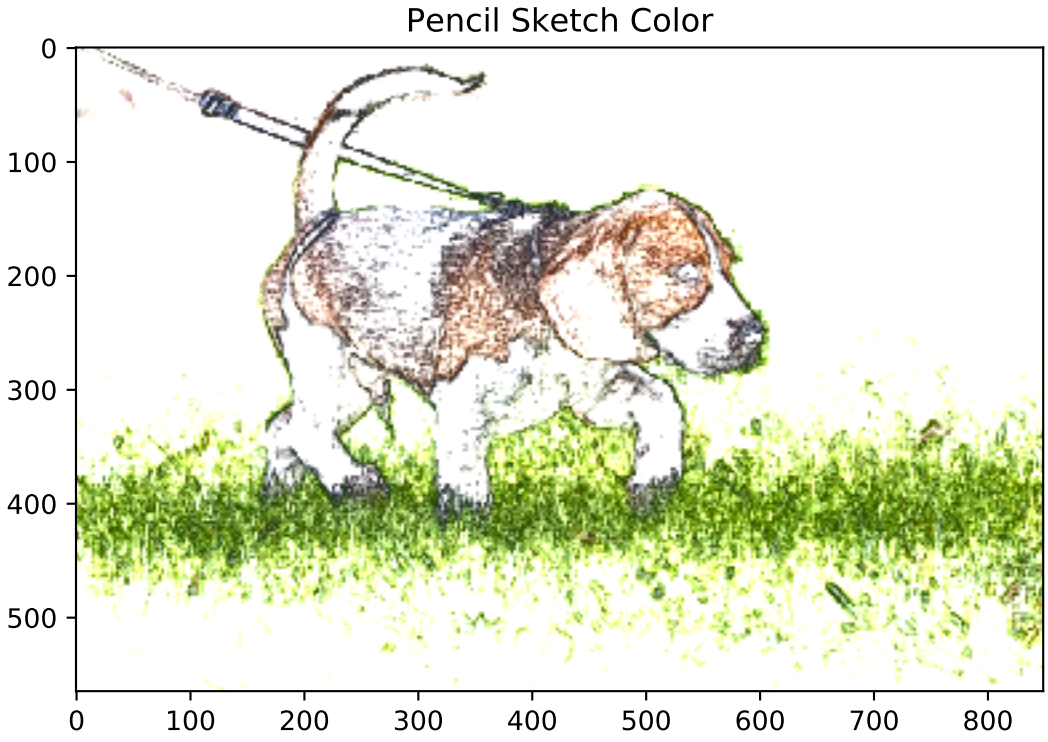

```
epf = cv2.edgePreservingFilter(src, flags=1, sigma_s=60, sigma_r=0.8)
imshow (epf, 'OpenCV Edge Preserving Filter')
```



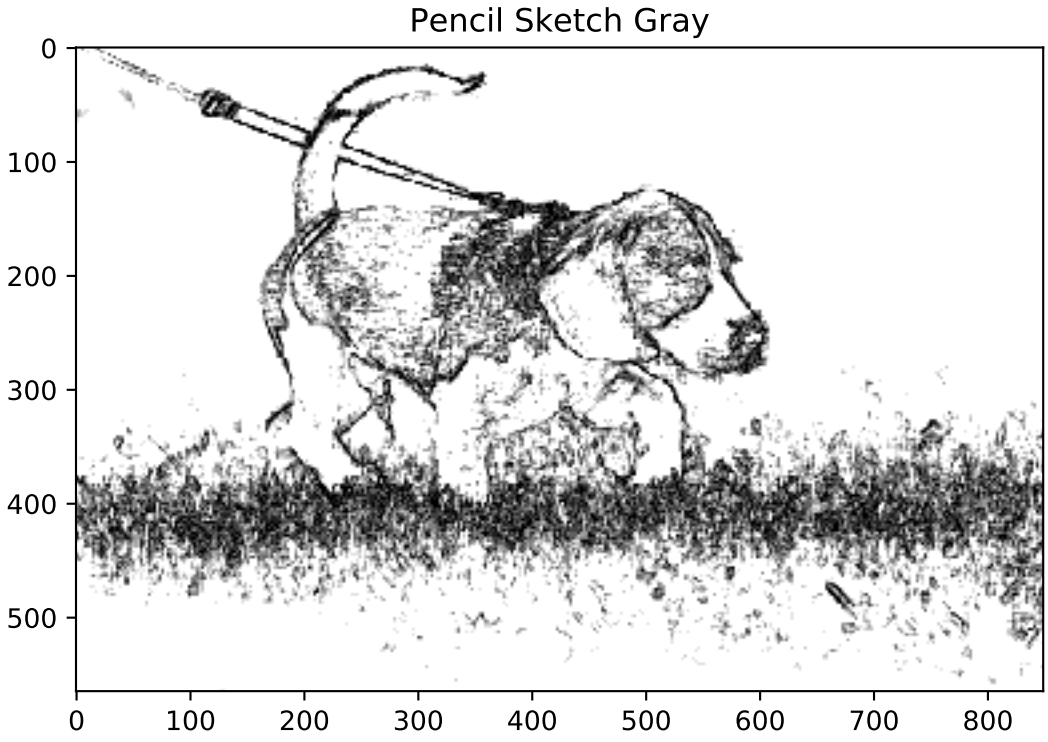

```
detf = cv2.detailEnhance (src, sigma_s = 10, sigma_r=0.2)
imshow (detf, 'Detail Enhancement Filter')
```



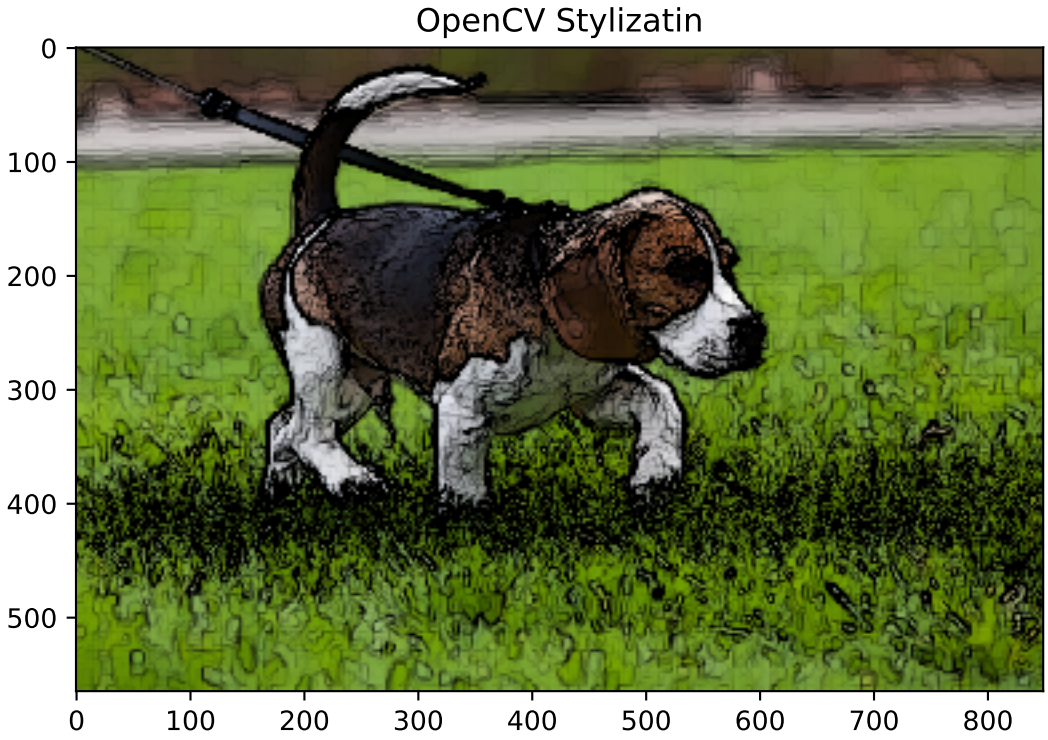

```
pencil_g, pencil_c = cv2.pencilSketch (src, sigma_s=60, sigma_r=0.07, shade_factor=0.1)
imshow (pencil_c, 'Pencil Sketch Color')
```




```
imshow (pencil_g, 'Pencil Sketch Gray')
```




```
styl = cv2.stylization (src, sigma_r=0.05, sigma_s=50)
imshow (styl, 'OpenCV Stylizatin')

# EOF
```



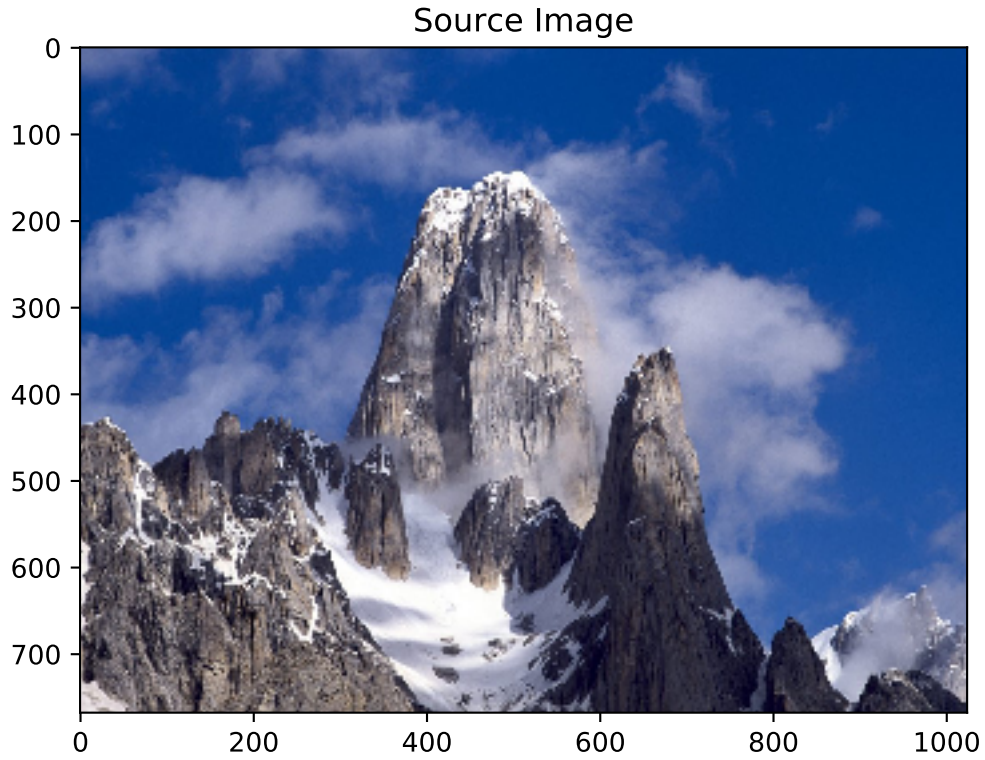
16.2 Hand-made cartoon-like filtering

```
import cv2
import numpy as np
import imageio
import matplotlib.pyplot as plt

# show the image
def imshow (img, title=None):
    if img.ndim == 3:
        plt.imshow (img)
    else:
        plt.imshow (img, cmap='gray')

    if title is None: title = 'imshow'
    plt.title (title)
    plt.pause (1)
    plt.close ()
#

img = imageio.imread('data/karakoram-imgur.com.jpg')
if img is None:
    print ('image file open error')
```

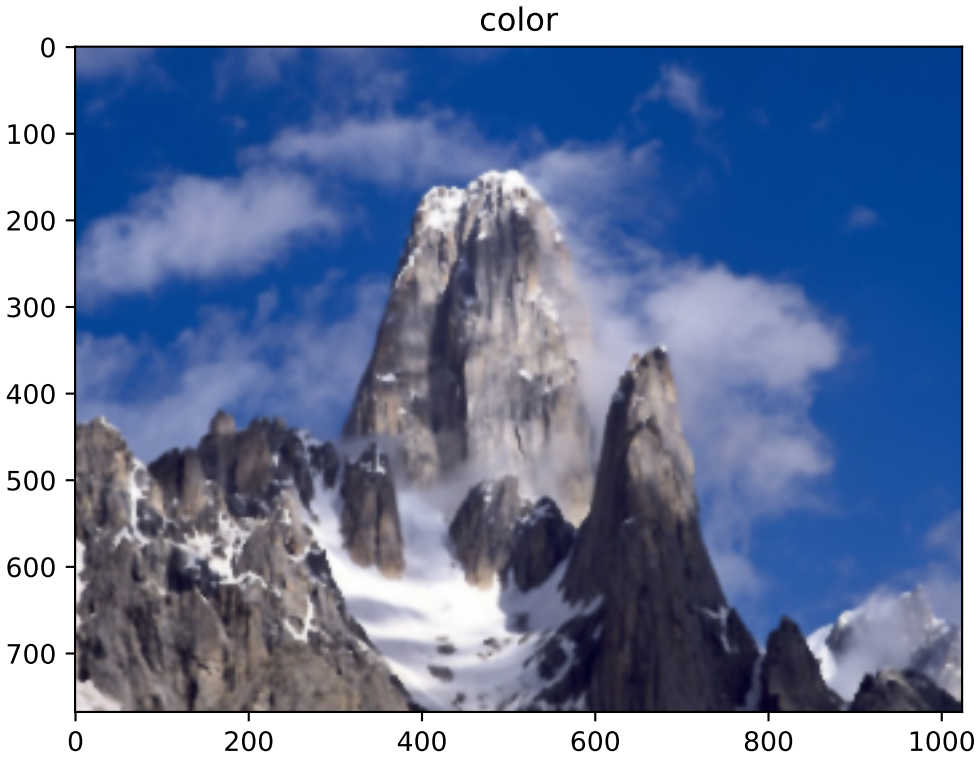
```
    sys.exit ()
#
print (img.shape)
```

```
## (768, 1024, 3)
```

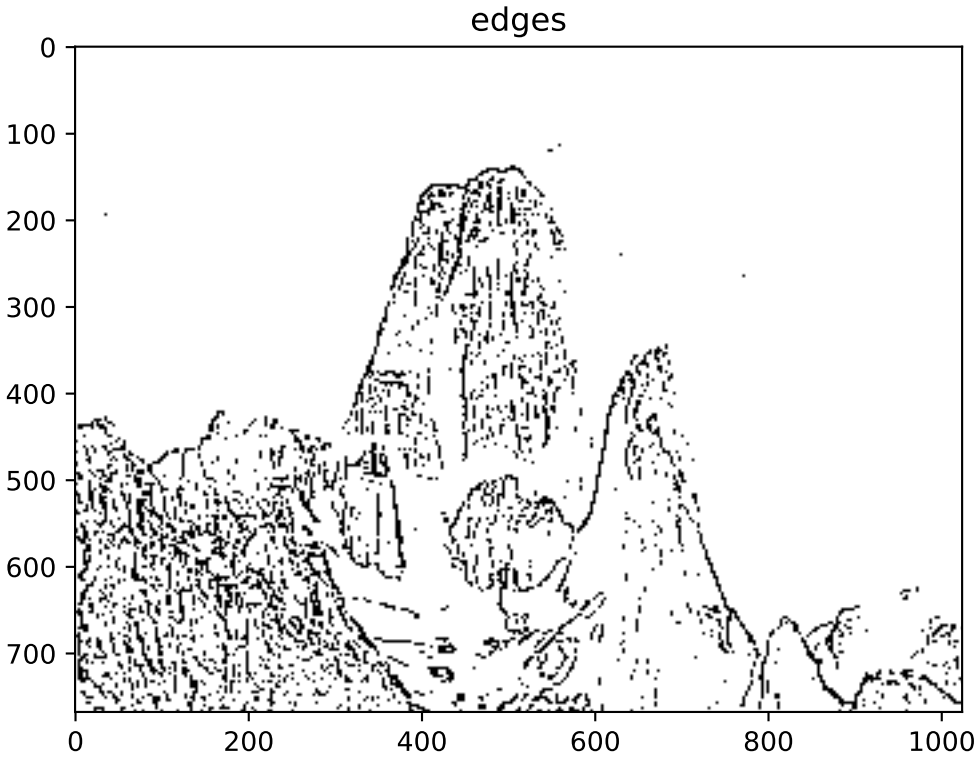
```
imshow (img, 'Source Image')


# 1) Edges
```



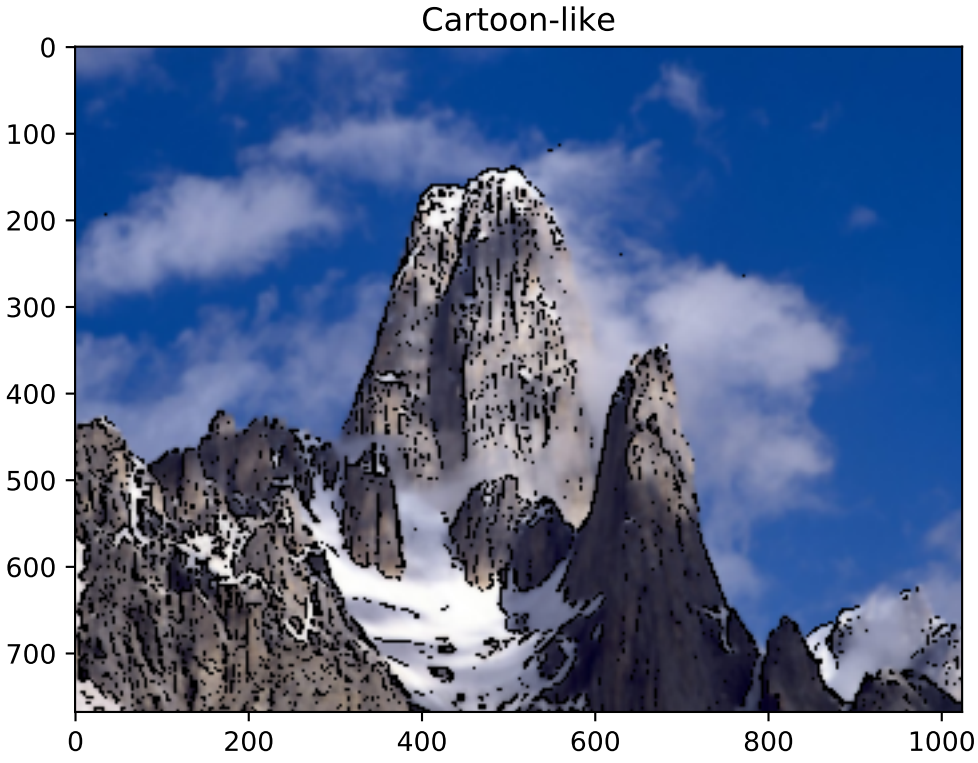

```
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
gray = cv2.medianBlur(gray, 5)
edges = cv2.adaptiveThreshold(gray, 255, cv2.ADAPTIVE_THRESH_MEAN_C, cv2.THRESH_BINARY, 9, 9)

# 2) Color
color = cv2.bilateralFilter(img, 9, 300, 300)

# 3) Cartoon
cartoon = cv2.bitwise_and(color, color, mask=edges)

# display
imshow(color, "color")
```




```
imshow(edges, "edges")
```




```
imshow(cartoon, "Cartoon-like")

# EOF
```


Cartoon-like
0
100
200
300
400
500
600
700
0
200
400
600
800
1000

Chapter 17

Drawing Text in Image with a Font (OTF) file

- Install Google Noto CJK Fonts
- Use `PIL` with `python`
- `PIL.ImageFont`
- Drawing anti-aliased unicode text with python
- Computer_font
- Outline font:
  - Outline fonts or vector fonts are collections of vector images, consisting of lines and curves defining the boundary of glyphs.
  - The primary advantage of outline fonts is that, unlike bitmap fonts, they are a set of lines and curves instead of pixels; they can be scaled without causing pixellation.
- OpenType Font
- ensuring that all of the required glyphs for a document are contained in one cross-platform font file throughout the workflow. Adobe opentype
- GNU Charmap
- OpenGL Text Rendering
- FreeType Library
- FreeType is a freely available software library to render fonts. -It is written in C, designed to be small, efficient, highly customizable, and portable while capable of producing high-quality output (glyph images) of most vector and bitmap font formats.
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