IMAGE PROCESSING TUTORIALS with PYTHON®

Yann GAVET
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Part I Première partie: MATLAB®

1 Ceci est un nom de Chapitre super long super super super super

Ceci est une note!

Ceci est une remarque.

1.1. Matlab correction

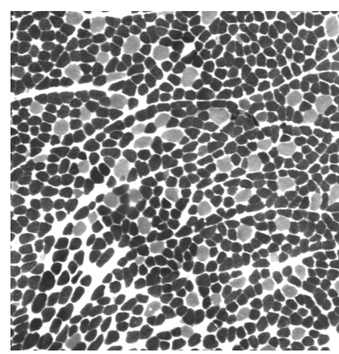
2 Ceci est un sujet

3 Introduction to image processing

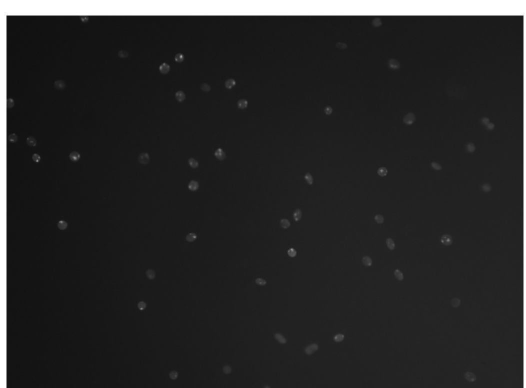
In this tutorial, you will discover the basic functions in order to load, manipulate and display images. The main informations of the images will be retrieved, like size, number of channels, storage class, etc. Afterwards, you will be able to perform your first classic filters.

The different processes will be realized on the following images:

(a) Retinal vessels.



(b) Muscle cells.



(c) Cornea cells (BIIGC, Univ. Jean Monnet, Saint-Etienne, France).

Figure 3.1: Image examples.

3.1 First manipulations

Image loading can be made by the use of the MATLAB® function imread. The visualization of the image in the screen is realized either by the MATLAB® function imagesc or imshow.

- Load and visualize the first image as below. Notice the differences.
- Look at the data structure of the image I such as its size, type....
- Visualize the green component of the image. Is it different from the red one? What is the most contrasted color component? Why?
- Enumerate some digital image file formats. What are their main differences? Try to write images with the JPEG file format with different compression ratios (0, 50 and 100), as while as the lossless compression, and compare.

See imwrite.

3.2 Image histogram

An image histogram represents the gray level distribution in a digital image. The histogram corresponds to the number of pixels for each gray level. The MATLAB® function that computes the histogram of any gray level image has the following prototype:

```
function h = histogram(I)
```

Compute and visualize the histogram of the image 'muscle.jpg'.

3.3 Linear mapping of the image intensities

The gray level range of the image 'cellules_cornee.jpg' can be enhanced by a linear mapping such that the minimum (resp. maximum) gray level value of the resulting image is 0 (resp. 255). Mathematically, it consists in finding a function $f(x) = ax + b$ such that $f(min) = 0$ and $f(max) = 255$.

?

- Load the image and find its extremal gray level values.
- Adjust the intensities by a linear mapping into $[0, 255]$.
- Visualize the resulting image and its histogram.

3.4 Color quantization

Color quantization is a process that reduces the number of distinct colors used in an image, usually with the intention that the resulting image should be as visually similar as possible to the original image. In principle, a color image is usually quantized with 8 bits (i.e. 256 gray levels) for each color component.

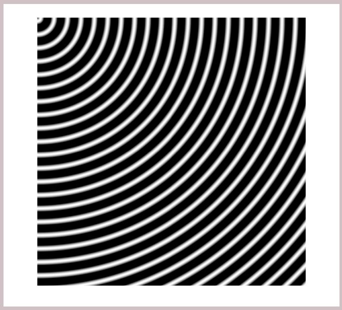
?

- By using the gray level image 'muscle', reduce the number of gray levels to 128, 64, 32, and visualize the different resulting images.
- Compute the different image histograms and compare.

3.5 Aliasing effect

?

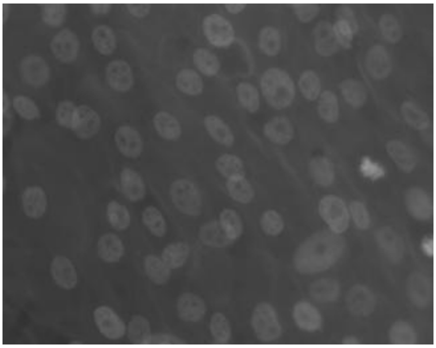
- Create an image (as below) that contains rings as sinusoids. The function takes two input parameters: the sampling frequency and the signal frequency.



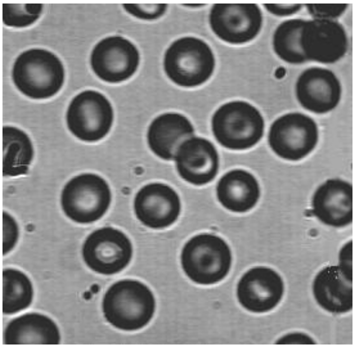
- Look at the influence of the two varying frequencies. What do you observe? Explain the phenomenon from a theoretical point of view.

3.6 Low-pass filtering

The different processes will be realized on the following images:



(a) osteoblast cells



(b) blood cells

Low-pass filtering aims to smooth the fast intensity variations of the image to be processed.

Test the low-pass filters 'mean', 'median', 'min', 'max' and 'gaussian' on the noisy image 'blood cells'.

The MATLAB® functions imfilter and nlfilter can be employed. Be careful to the function options for border problems. Also, the MATLAB® function fspecial enables an operational window to be generated.

Which filter is suitable for the restoration of this image?

3.7 High-pass filtering

High-pass filtering aims to smooth the low intensity variations of the image to be processed.

- Test the high-pass filters HP on the two initial images in the following way: $HP(f) = f - LP(f)$ where LP is a low-pass filtering (see the previous exercise).
- Test the Laplacian (high-pass) filter on the two initial images with the following convolution mask:

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & +8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

3.8 Derivative filters

Derivative filtering aims to detect the edges (contours) of the image to be processed.

- Test the Prewitt and Sobel derivative filters (corresponding to first order derivatives) on the image 'blood cells' with the use of the following convolution masks:

$$\begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ +1 & +1 & +1 \end{bmatrix}$$

$$\begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix}$$

- Look at the results for the different gradient directions.

- Define an operator taking into account the horizontal and vertical directions.

Remark : the edges could be also detected with the zero-cressings of the Laplacian filtering (corresponding to second order derivatives).

3.9 Enhancement filtering

Enhancement filtering aims to enhance the contrast or accentuate some specific image characteristics.

- Test the enhancement filter E on the image 'osteoblast cells' defined as: $E(f) = f + HP(f)$ where HP is a Laplacian filter (see tutorial about enhancement.).

- Parameterize the previous filter as: $E(f) = \alpha f + HP(f)$, where $\alpha \in \mathbb{R}$.

3.10 Open question

Find an image filter for enhancing the gray level range of the image 'osteoblast cells'.

3.11. Python correction

```python
# display images
import matplotlib.pyplot as plt

# ndimage defines a few filters
from scipy import misc, ndimage

# numeric calculation
import numpy as np

# measure time
import time

# read and save images
import imageio
```

3.11.1 First manipulations

Open, write images

The following file loads the ascent image and display it. The `print` function is optional.

```python
# load file ascent
ascent = misc.ascent()

# load file cerveau.jpg
brain = imageio.imread('cerveau.jpg')
print(type(brain))
print(brain.shape, brain.dtype)

# save file
imageio.imwrite('test.png', brain)
```

Display images

You can modify to previous example to add the following lines:

```
plt.imshow(ascent)
plt.show()
```

Notice that you have to close the image window to write commands again. Also, the colormap is not the good one by default (see Fig. 3.2).

```
plt.figure(figsize=(10, 3.6))

# first subplot
plt.subplot(131)
plt.imshow(ascent)

# second subplot
plt.subplot(132)
plt.imshow(ascent, cmap=plt.cm.gray)
plt.axis('off')

# third subplot (zoom)
plt.subplot(133)
plt.imshow(ascent[200:220, 200:220], cmap=plt.cm.gray, interpolation='nearest')

plt.subplots_adjust(wspace=0, hspace=0.,
                    top=0.99, bottom=0.01,
                    left=0.05, right=0.99)
plt.show()
```

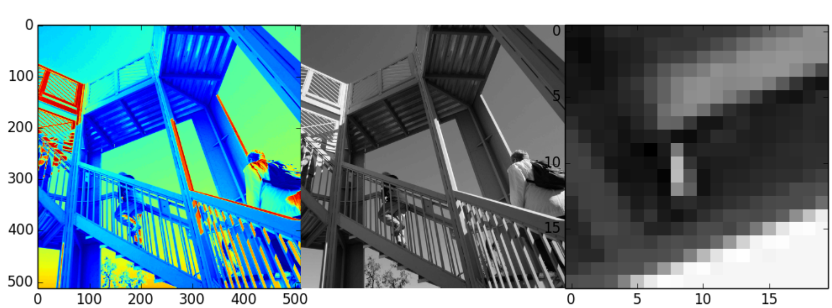


Figure 3.2: Displaying images with an adapted colormap.

Histogram

To plot the histogram of an image, you can use the hist function (see result in Fig. 3.3).

```python
plt.hist(ascent.flatten(), 256)
plt.show()
```

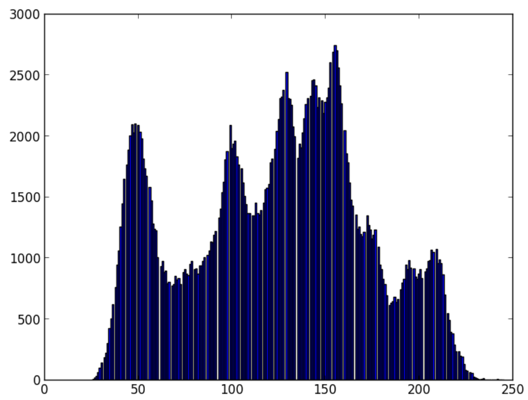


Figure 3.3: Histogram of ascent image.

You can also write your own code. The execution time is higher for these two functions than for the previous one.

```python
# Histogram function with 2D image
def compute_histogram(image):
    tab = np.zeros((256, ), dtype='I')
    X, Y = image.shape
    for i in range(X):
        for j in range(Y):
            tab[image[i,j]]+=1

    return tab
```

```python
# Histogram function with flatten image (vector)
def compute_histogram2(image):
    im = image.flatten()
    tab = np.zeros((256, ), dtype='I')
    for i in im:
        tab[i]+=1
    return tab
```

The following code presents a comparison of the different method for histogram computation.

```
# load ascent image and compute histograms
ascent = misc.ascent()
t0 = time.clock()
h = compute_histogram(ascent)
t1 = time.clock()
h2=compute_histogram2(ascent)
t2 = time.clock()

# .... plots
print "execution time 2D:%g" %(t1-t0)
plt.subplot(131)
plt.plot(h)
plt.title('2D function')

print "execution time 1D:%g" %(t2-t1)
plt.subplot(132)
plt.plot(h2)
plt.title('1D function')

# last plot: with matplotlib function
plt.subplot(133)
t3 = time.clock()
plt.hist(ascent.flatten(), 256)
t4 = time.clock()
print "execution time matplotlib:%g" %(t4-t3)

# display
plt.show()
```

The console outputs the following computation durations:

```
execution time 2D: 1.40284 s
execution time 1D: 1.27649 s
execution time matplotlib: 0.261095 s
```

3.11.2 Linear mapping of the image intensities

The linear mapping is a simple method that stretches linearly the histogram. If displayed with `matplotlib`, the images is linearly stretched, thus the modification cannot be observed.

```python
def image_stretch(image):
    # return image with new maximum and minimum at 255 and 0
    minimum = image.min();
    maximum = image.max();
    a = 255/(maximum-minimum);
    b = -255*minimum/(maximum-minimum);

    return a*image+b;
```

3.11.3 Color quantization

The following code uses the properties of integer operations to round values to the nearest integer. Illustration is presented Fig. 3.4.

```python
q4 = ascent / 4*4;
q16= ascent /16*16;
q32= ascent /32*32;
```

Figure 3.4: ascent image q32.

3.11.4 Aliasing effect

```python
# aliasing effect (Moire)
def circle(fs, f):
    # Generates an image with aliasing effect
    # fs: sample frequency
    # f : signal frequency
    t = np.arange(0,1,1./fs);
    ti, tj = np.meshgrid(t,t);
    C = np.sin(2*np.pi*f*np.sqrt(ti**2 +tj**2));
    return C
```

The image of Fig. 3.5 is generated with the following code.

```python
C = circle(300,50);
plt.imshow(C, cmap=plt.cm.gray);
plt.show()

imageio.imwrite('moire.png', C);
```

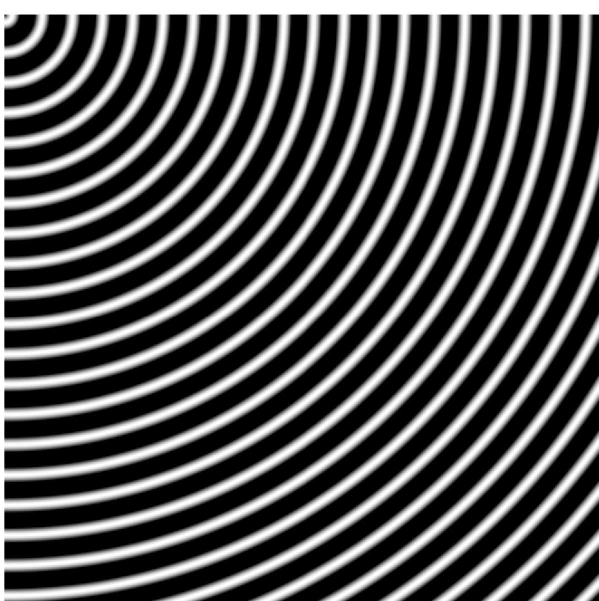


Figure 3.5: Moiré effect, generated with $f_s = 300$ and $f = 50$.

3.11.5 Low-pass filtering

The mean filter is illustrated in Fig. 3.6.

```python
# mean on a 3x3 neighborhood
m3 = ndimage.filters.uniform_filter(ascent)
m25= ndimage.filters.uniform_filter(ascent, 25)

plt.subplot(121)
plt.imshow(m3, cmap=plt.cm.gray)
plt.axis('off')
plt.title('3x3 mean filter')

plt.subplot(122)
plt.imshow(m25, cmap=plt.cm.gray)
plt.axis('off')
plt.title('25x25 mean filter')

plt.show()
```

(a) Neighborhood of size 3x3.

(b) Neighborhood of size 25x25.

Figure 3.6: Mean filters.

Gaussian filter

The gaussian filter is presented in Fig. 3.7.

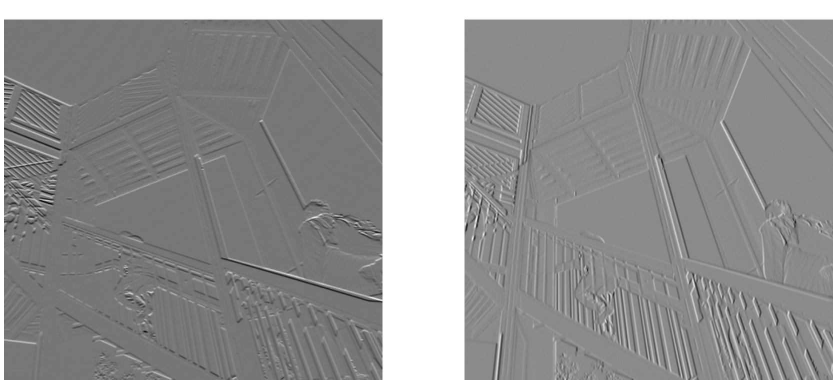
```python
# ascent image
ascent = misc.ascent()

# Gaussian filter
gaussian= ndimage.filters.gaussian_filter(ascent, 5)
```

Figure 3.7: Gaussian filter of size 5.

3.11.6 Derivative filters

Derivative filters (Prewitt, Sobel...) use a finite derivation approximation. They are very sensitive to noise (as every system using a derivation). The gradient is defined as a vector, and a norm should be used to display a resulting image. Notice that with these filters, the connexity of the contours is not preserved. Illustration is proposed in Fig. 3.8.

```python
# ascent image
ascent = misc.ascent()
ascent.astype('int32');

# Prewitt filter
prewitt0 = ndimage.filters.prewitt(ascent, axis=0)
prewitt1 = ndimage.filters.prewitt(ascent, axis=1)

# Sobel filter
dy = ndimage.filters.sobel(ascent, axis=0) # vertical
dx = ndimage.filters.sobel(ascent, axis=1) # horizontal
mag = np.hypot(dx, dy) # magnitude
sobel = mag * 255.0 / mag.max() # normalize (Q&D)

# display results
plt.subplot(131)
plt.imshow(prewitt0, cmap=plt.cm.gray)
plt.axis('off')
plt.title('Prewitt filter axis 0')

plt.subplot(132)
plt.imshow(prewitt1, cmap=plt.cm.gray)
plt.axis('off')
plt.title('Prewitt filter axis 1')

plt.subplot(133)
plt.imshow(sobel, cmap=plt.cm.gray)
plt.axis('off')
plt.title('Sobel filter ')

plt.show()
```



(a) Prewitt filter for axis x.

(b) Prewitt filter for axis y.

Figure 3.8: Prewitt filter.

4 Ceci est un sujet

4.1 section

4.2 Ceci est un titre de section supersuper long qui dépasse la ligne

4.2.1 subsection

subsubsection

```matlab
function t = test (A)
% this is a test function
A = rand (25,2) ;
imagesc(A);
[X, Y] = meshgrid (1:10, 1:10) ;
```

```python
def myFunction(toto):
    # this is a test function
    return True;
```

4.3. Matlab correction

Command window

```
test
```

4.3.1 subsection

4.3.2 Matlab environments

Deux environnements doivent être présentés maintenant, sauf si excludecomment est utilisé:

This is a MATLAB® mremark environment.

Informations

This is a MATLAB® mhelp.
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Voilà, c'est fait.

4.4. Python correction

```
This is a shell to show python results .
```

4.4.1 subsection

4.4.2 Python environments

Informations

This is a python phelp environment

?

this is a serie of questions, available with qbox.

- ATTENTION: L'UTILISATION DE PLUSIEURS PAGES SEMBLENT POSER PROBLÈME.

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Figure 4.1: Figure example

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4.5 Test existence of label

Label “fig:test” does’nt exist! New label: 4.1.

5 Ceci est encore un nom de Chapitre supersuper long

5.1 section

5.2 section

5.3 section

5.4 section

5.5 section

5.6 section

5.7 section

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5.11 section

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5.16 section

5.17 section

5.18 section

Part II 2nd part

6 Chapitre

7 New chapter

7.1 sec of new chapter

8 New chapter

9 New chapter

10 New chapter

11 New chapter

12 New chapter

13 New chapter

14 New chapter

15 New chapter

16 New chapter

17 New chapter

17.1 sec of new chapter

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Part III References

Image processing tutorials with python This book is a collection of tutorials and exercises given at MINES Saint-Etienne as part of the Civil Mining Engineer course. In recent years, project-based learning has given students a particular motivation by illustrating theoretical concepts with real and concrete applications. Whether you are in the early years of your university studies, in preparatory classes for the French Grandes Ecoles or in an engineering school, or even as a teacher, this book is made for you. You will find a large number of tutorials, classified by field, to familiarize yourself with the theoretical concepts of image processing and analysis.

Go to http://iptutorials.science to download the complete codes in python.

Yann GAVET received his “Ingénieur Civil des Mines de Saint-Étienne” diploma in 2001, obtained a master of science in 2004 and defended his PhD thesis in 2008. He teaches signal processing, image processing and pattern recognition as well as C programming at a master level.

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