Introduction to Computer Vision

ISAE-SUPAERO

OTSU - Earth Observation & Space Science

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The objective of this course is to introduce Image Processing and Computer Vision principles under MatLab.

1 Basics

Commands `imread` et `imshow` allow to respectively load and display an image.

▶ **Question 1** *Load and Display a grayscale image and a color image. How do you interpret the image coding under* MatLab*? What is the data type?*

The command `figure` open a new window and increment the numbering. Open and display all images. `Close all` allows to close all windows at once.

1.1 Greyscale Image Coding

Now, we will build the matrix whose image could be displayed on the screen. By default, data type is double. Check for min (for black) and max (for white) values in double type.

▶ **Question 2** *Build a matrix with a gradual value of intensity and an horizontal line with a constant value; the representative image is shown Fig. 1.*

Figure 1: Grayscale Illusion

▶ **Question 3** *Build a matrix of black & white stripes with a variable width (T), as shown Fig. 2.*

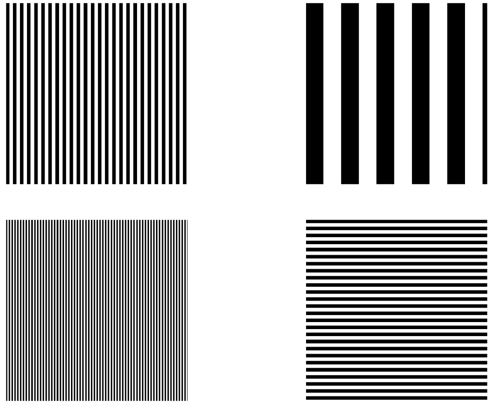

Figure 2: Stripes

1.2 Colour Image Coding

▶ **Question 4** *Next, display Teinte.jpg and its red, green and blue components. Interpret and analyse. Same withoeil.jpg, cargo.jpg and CoulAdd.jpg.*

▶ **Question 5** *Build and display the french flag. Build and display your flag.*

▶ **Question 6** *Use the HSV code (with the command* `rgb2hsv` *and interpret images. How is the type of the new matrix? Build and display the image Fig. 3.*

`rgb2gray` allows to transform a colour image to a grayscale image:

$$I = \alpha \times r + \beta \times g + \gamma \times b$$

▶ **Question 7** *What are the values of α, β and γ ?*

1.3 Histograms

It is easy to display the histogram of an image under MatLab with the command `imhist`.

▶ **Question 8** *What is an histogram? What is the use? Display and interpret histograms of images?*

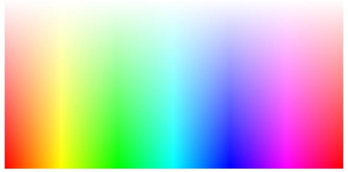

Figure 3: HSV Color Space

It is also easy to manage histogram with the command `histeq`.

▶ **Question 9** *Work the mysterious images called Imagex.bmp and Imagexx.bmp.*

▶ **Question 10** *Load ans display SpainBeach.png and isolate the beach.*

1.4 Filtering

Filtering can be associated to blur and to edge detection. Commands `imfilter` and `fspecial` can be used to respectively filter images and define kernel (which can be also defined as a matrix).

▶ **Question 11** *Apply blur Filtering and Edge filtering on the Stripes images and on a 'real' image. What are the main associated Kernels ?*

▶ **Question 12** *Thanks to successive filtering operators, isolate the main 5 stars of the image Etoile.png.*

2 Fourier Transform

The Fourier transform is a very powerful tool to extract information on an image. Let us recall these formulas:
DFT: Direct Fourier Transform:

$$F(p,q) = \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} I(n,m).e^{-j(\frac{2\pi}{N})pn}.e^{-j(\frac{2\pi}{M})qm}$$

IFT: Inverse Fourier Transform:

$$I(m,n) = \frac{1}{MN} \sum_{p=0}^{N-1} \sum_{q=0}^{M-1} F(p,q).e^{+j(\frac{2\pi}{N})pn}.e^{+j(\frac{2\pi}{M})qm}$$

BE1 : Introduction to Computer Vision *Emmanuel Zenou*

MatLab calculates the FT of an image thanks to `fft2` (followed by `fftshift`).

▶ **Question 13** *Get the FT and analyze the spectrum if images with stripes (Fig. 2).*

▶ **Question 14** *Blur the image with different kernels and interpret the spectrum.*

▶ **Question 15** *Write a program that extracts the specific field in the image Champs.jpg (see Fig. 4).*

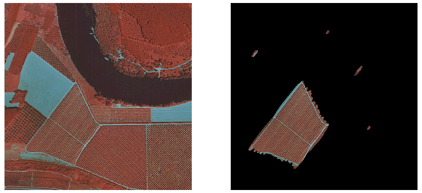

Figure 4: Extraction du champ par transformée de Fourier.

3 Deblurring

In this section, we will see some examples of image deblurring algorithms through linear modelization.
The is main source of blur in an image:

- Bad focalization,
- Moving blur,
- Atmosphere turbulences
- etc.

3.1 Linear Modelization

As a first approximation, a blurred image could be modeled as following:

$$\mathcal{Y} = \mathcal{H} * \mathcal{I} + \mathcal{B}$$

with

- $\mathcal{Y}$ the blur image to be restored
- $\mathcal{H}$ the convolution kernel,

Computer Vision *ISAE-SUPAERO*

- $\mathcal{I}$ the original image to be estimated,
- et $\mathcal{B}$ a Gaussian additive noise.

▶ **Question 16** *What's happen on the spectral domain?*

3.2 Blur Estimation

The objective is here to estimate a posteriori the value of T, *i.e.* from the blurred image.

Let's take the image of Toulouse and blur this image with a $(2T+1)$-sized square kernel (Typically $T = 3$). The convolution kernel is thus $h(x,y) = \alpha$ if $|x| \leq T$ or $|y| \leq T$, with $\alpha = \frac{1}{(2T+1)^2}$.

In dim 1, $h(x) = \sqrt{\alpha}$ si $|x| \leq T$. The DFT is

$$\mathcal{H}(u) = \sum_{x=-T}^{+T} h(x) e^{-j2\pi\frac{ux}{N}} = \frac{1}{2T+1} \sum_{x=-T}^{+T} w^x$$

However,

$$\sum_{x=-T}^{+T} w^x = \frac{w^{-T} - w^{T+1}}{1-w} = \frac{w^{-T-\frac{1}{2}} - w^{T+\frac{1}{2}}}{w^{-\frac{1}{2}} - w^{\frac{1}{2}}}$$

Thus

$$\mathcal{H}(u) = \frac{1}{2T+1} \frac{sin(2\pi\frac{u}{N}(T+\frac{1}{2}))}{sin(\pi\frac{u}{N})}$$

In dim 2, $h(x,y) = h(x)h(y)$

▶ **Question 17** *Show that the function $\mathcal{H}(u)$ could be similar to a cardinal sinus by superposing the two functions. What conclusion could you give from this properties? Could you estimate T ?*

Compare the the original image spectrum and the blurred image spectrum (using eventually the log function):

▶ **Question 18** *Estimate T.*

3.3 Image Deblurring

Now, image deblurring (or image restauration) could be done by many methods. Let us focus on two of them

- Inverse Filtering,
- Wiener Filtering.

Let $g(x,y)$ be the inverse filter of $h(x,y)$. In the spectral Domain, we have:

$$\mathcal{G} = \frac{1}{\mathcal{H}}$$

The estimated restaured image $\widehat{\mathcal{I}}$ is:

$$\widehat{\mathcal{I}} = \mathcal{G}\mathcal{Y} = \widehat{\mathcal{I}} = \mathcal{G}\mathcal{H}\mathcal{I} + \mathcal{G}\mathcal{B} = \widehat{\mathcal{I}} = \mathcal{I} + \mathcal{G}\mathcal{B}$$

The following program allows to apply this process:

```
SeuilMax = 11 ;
hh = zeros(TailleImage);
centre = [1 1] + floor(TailleImage/2) ;
ext = (TailleFiltre-[1 1])/2;
ligs = centre(1) + [-ext(1):ext(1)];
cols = centre(2) + [-ext(2):ext(2)];

h = ones(TailleFiltre)/prod(TailleFiltre);
hh(ligs,cols) = h;
hh = ifftshift(hh);

H = fft2(hh);

ind = find(abs(H)<(1/SeuilMax));
H(ind) = (1/SeuilMax)*exp(j*angle(H(ind)));

G = ones(size(H))./H;

(...)
```

▶ **Question 19** *Complete this program (only 2 lines!) to process inverse filtering method.*

▶ **Question 20** *What's happen with the image* `marcheur.jpg` *?*

The Weiner filtering method is based on the MSE between the original image and the estimated restaured image:

$$e_{MSE} = E[|\widehat{\mathcal{I}}(u,v) - \mathcal{I}(u,v)|^2] = E[|\widehat{\mathcal{I}} - \mathcal{I}|^2]$$

However

$$\widehat{\mathcal{I}} - \mathcal{I} = (\mathcal{G}\mathcal{H} - 1)\mathcal{I} + \mathcal{G}\mathcal{B}$$

Thus

$$E[|\widehat{\mathcal{I}} - \mathcal{I}|^2] = |\mathcal{G}\mathcal{H} - 1|^2 E[|\mathcal{I}|^2] + |\mathcal{G}|^2 E[|\mathcal{B}|^2]$$

One may prove that this function has a minimum and, in such a case, with $\rho = \frac{E[|\mathcal{B}|^2]}{E[|\mathcal{I}|^2]}$,

$$\mathcal{G}(u,v) = \frac{\mathcal{H}^*(u,v)}{|\mathcal{H}(u,v)|^2 + \rho}$$

The Weiner method is already implemented im MatLab:

```
RestW = deconvwnr(If,h);
```

▶ **Question 21** *Restaure the blurred images and compare with the inverse filtering method.*