ESIEE PARIS

IMC5-1IA (image analysis).

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Introduction

- What is an image?
  - We will see many examples
- What is image analysis and image processing?
  - We will see many examples
- Software to do image analysis and processing

Introduction

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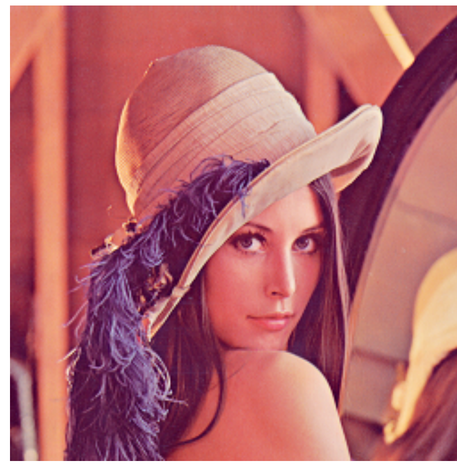
Images ?

In everyday life

Black and white
(binary)

Greyscale



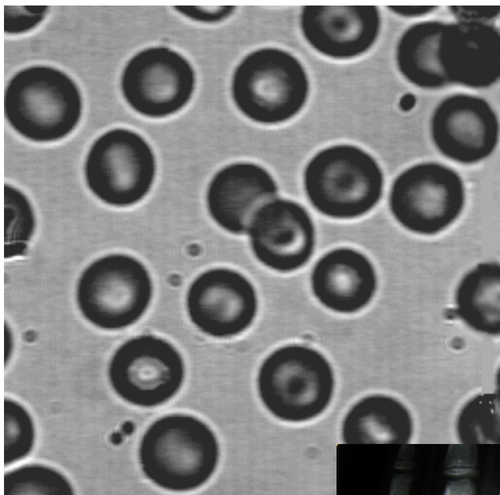
color

Image sequence
(video)

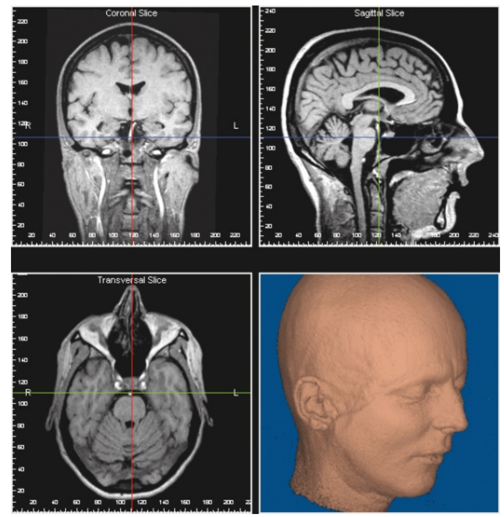
Images

Biology – Medical Examples:

Microscopy
(blood)

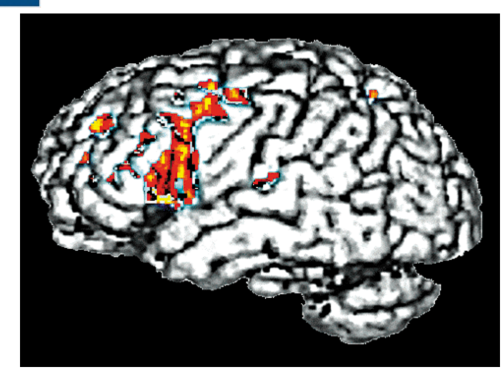


X-Ray



MRI(3D)

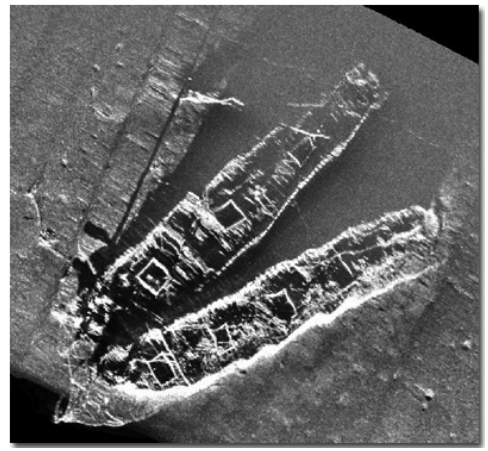
Fonctional MRI
(3D+t)



Images?

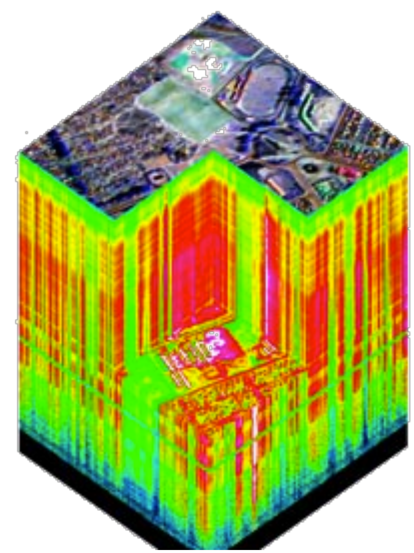
Teledection, Examples :

Radar

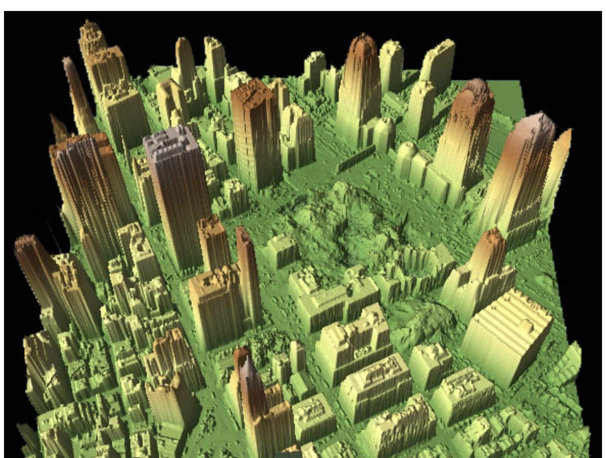


Sonar

Hyperspectral



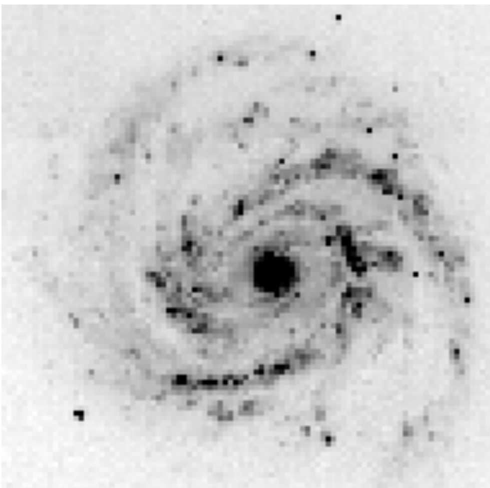
Lidar



Images?

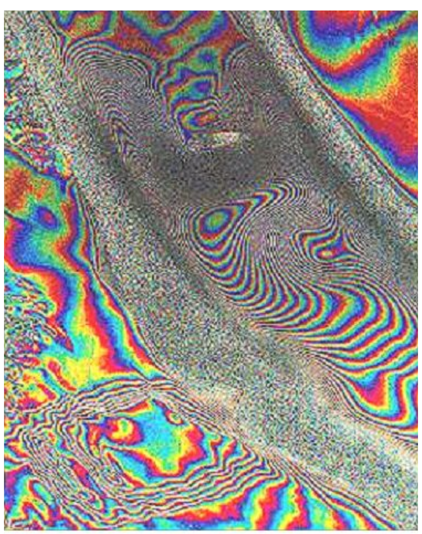
Physics, Examples :

Astronomy
(Galaxy in UV)



Electron
microscopy
(snowflakes)

Radar interferometry
(glacier)

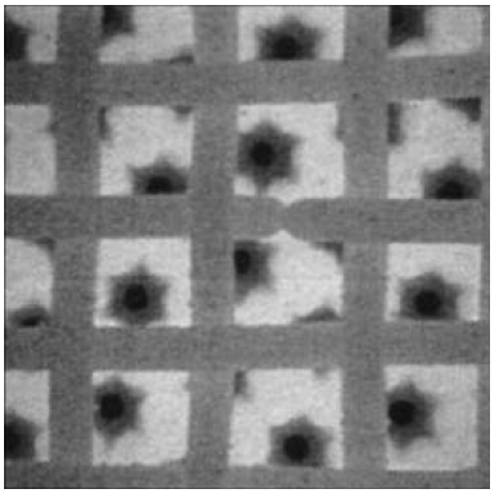


Bull chamber
(particule
collision)

Images?

Industrial Examples :

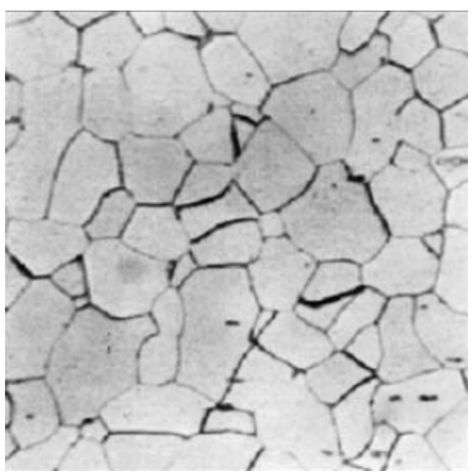
Gas burner
(thermal power plant)



Quality control on
bottles

2D Bar codes

Aluminium



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Analysis versus processing

- Image Processing: to get a novel image from another one (filtering)
  - Goal: enhance the quality of an image
- Image Analysis: to compute measurements on an image
  - Generally uses some image processing steps

- In this course, we will not present 3D visions (see the Computer Vision course)

Image Processing
Image filtering

- Sharpening :


- Histogram correction:


Image processing

image Restoration

- Denoising:

- Debluring :

Image processing

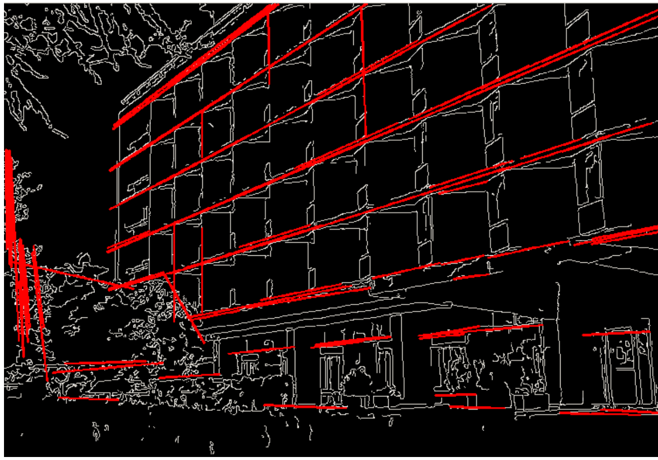
Image filtering

- Inpainting:

- Intelligent resizing:

Image analysis

- Line detector



- Interest point detection

Image analysis

- Segmentation

- Object detection

Image analysis

- Pattern recognition

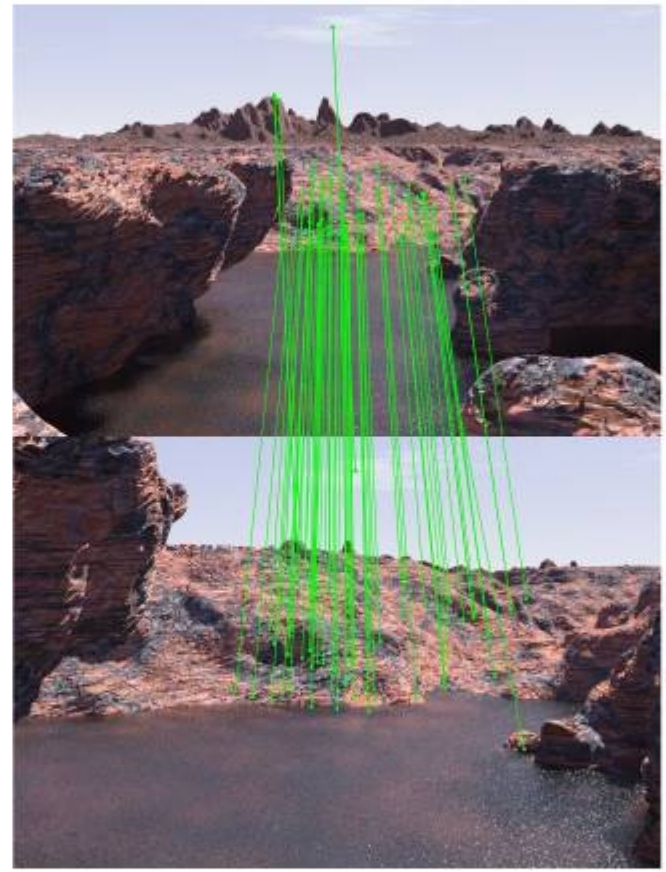


Image analysis

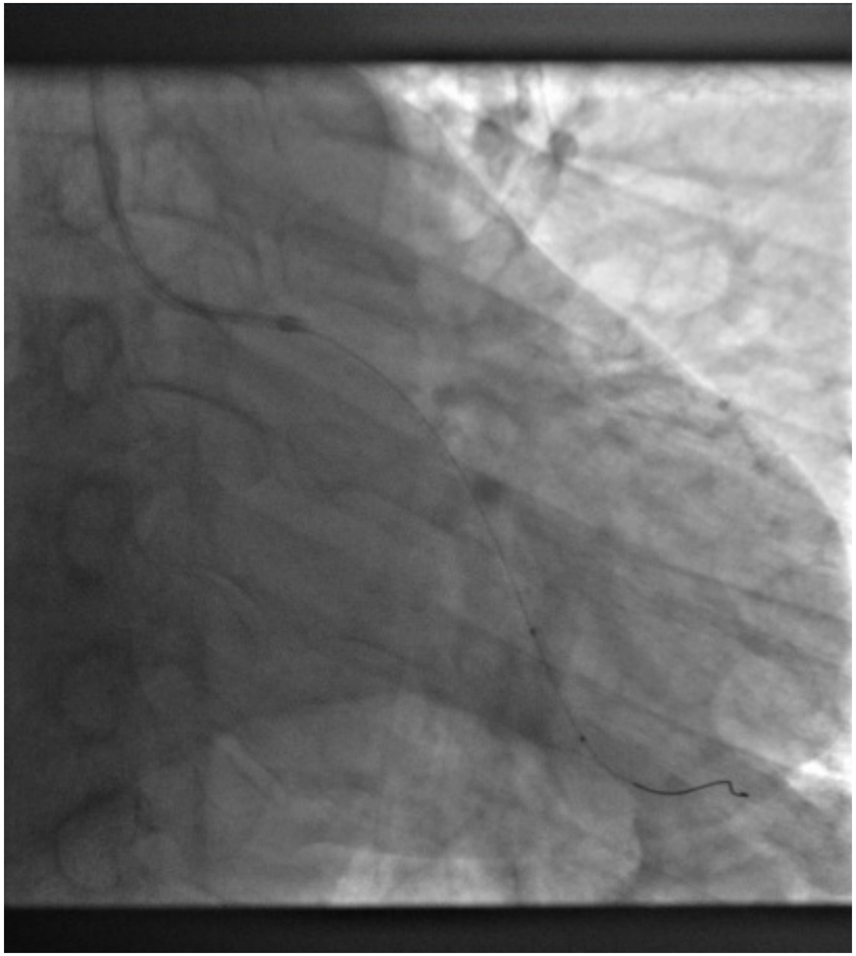
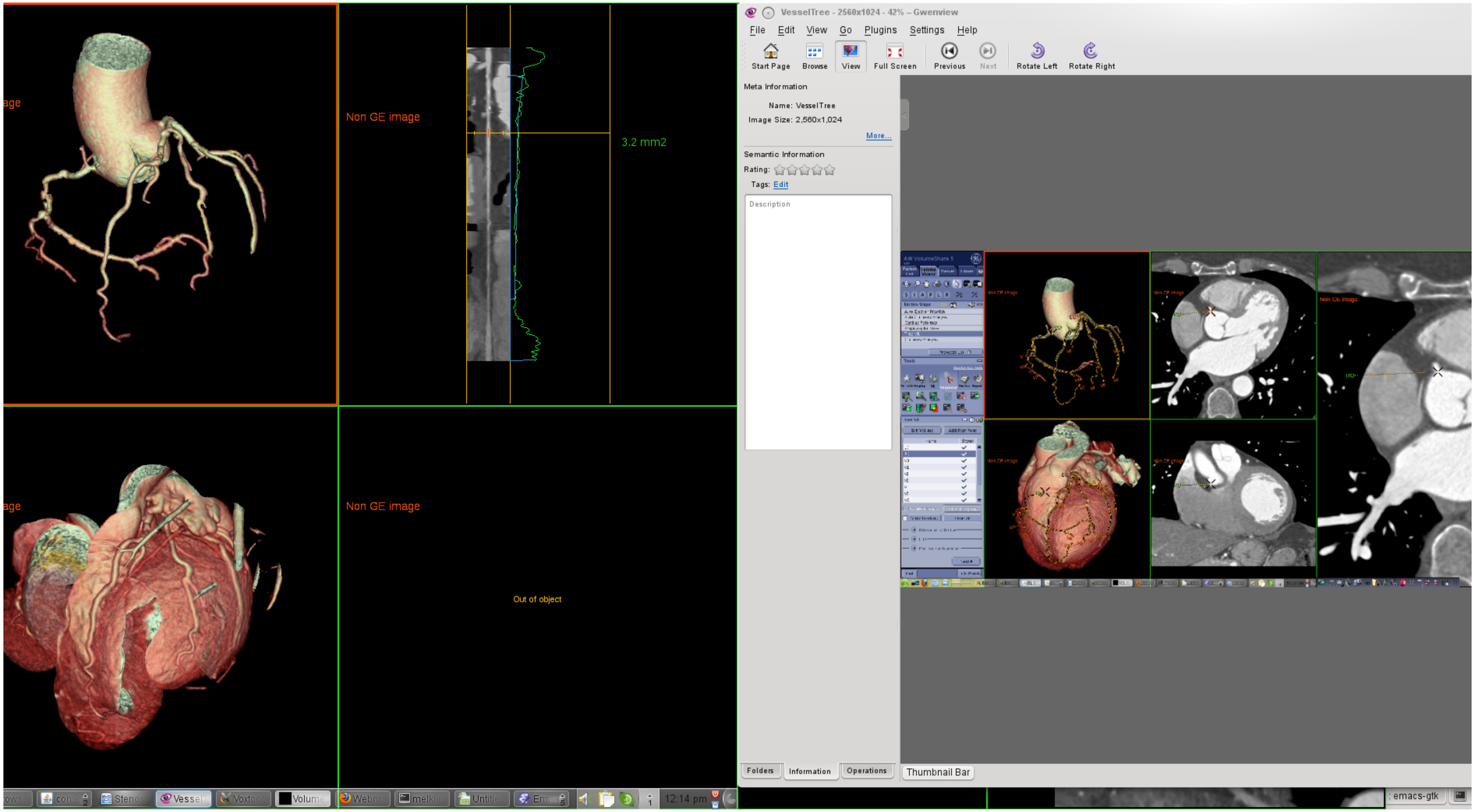


Image analysis

- Measure, caracterisation :

Image analysis



Introduction

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Software
Questions

- How to put into action an image processing method?

- Automated, semi-automated or manual solution

- Various types of software
  - Command-line software
  - Programming-environment
  - Libraries of operators
  - Visual programming software
  - Image editing software

Software

Command-line software

- User-interface : command line (unix shell type)
- Useful for batch processing
- Some examples:
  - Netpbm : http://netpbm.sourceforge.net
  - ImageMagick : http://www.imagemagick.org
  - Pink: http://pinkhq.com

Software
programing environments

- Interpreted shell-script in a specific language (open source or private)

- Intermediate level for instructions and data-structures

- Allows for the design of whole processing chains

- A few examples:
  - Matlab : http://www.mathworks.fr/
  - Scilab : http://www.scilab.org/
  - Visilog : http://www.noesisvision.com/
  - Pink+python: http://pinkhq.com

Software
Libraries of operators

- Writing of a software in a classical language
- Low level instructions
- More time to write a complete solution
- Many more possibilities
- A few examples:
  - OpenCV (C++) : http://sourceforge.net/projects/opencvlibrary/
  - ITK (C/C++) : http://www.itk.org/
  - Olena (C++) : http://*olena.lrde.epita.fr/*
  - Pink: http://pinkhq.com

Software

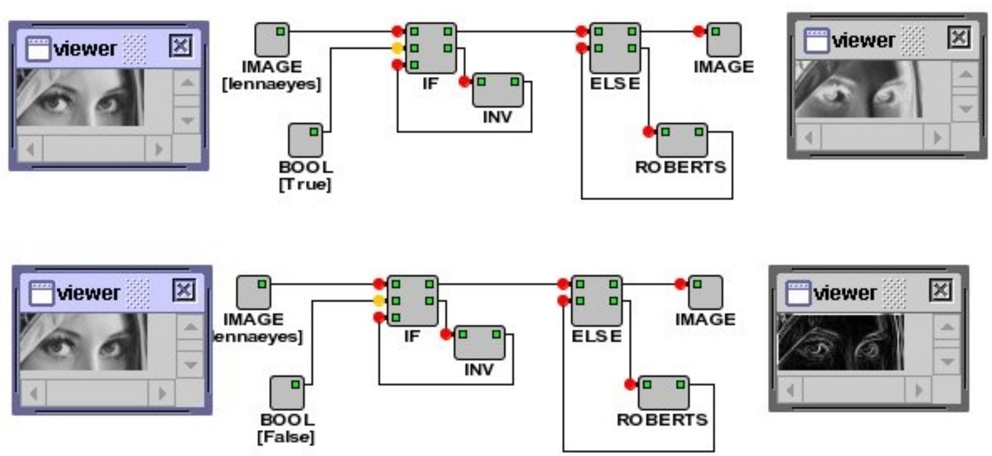
Image editing software

- For the public-at-large, intuitive user interface
- Useful when we want to quickly process a single image
- More difficult in case of batch processing
- A few examples:
  - Photoshop
  - GIMP
  - ImageJ

Software

Visual programing software

- Chaining processing is simple
- More difficult to begin with
- Allows complex operations
- A few examples :
  - Visiquest (ex-Khoros
  - Labview
  - NeatVision



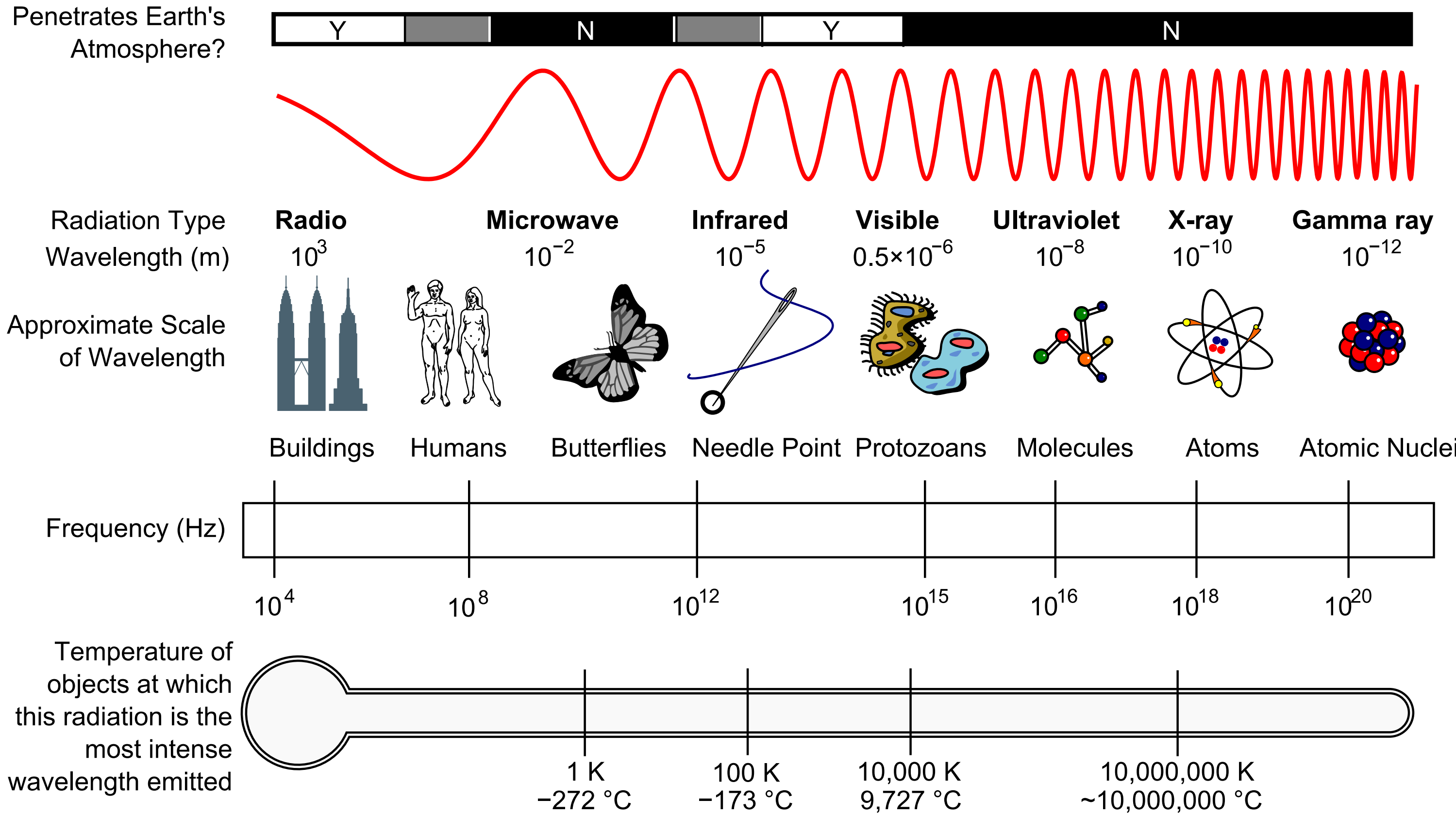
Some references

- Gonzales and Woods, *Digital Image Processing*, Prentice Hall
- Pratt, *Digital Image Processing*, Wiley
- Soille, *Morphological Image Analysis*, Springer-Verlag
- Najman and Talbot (ed.), *Mathematical Morphology*, Wiley

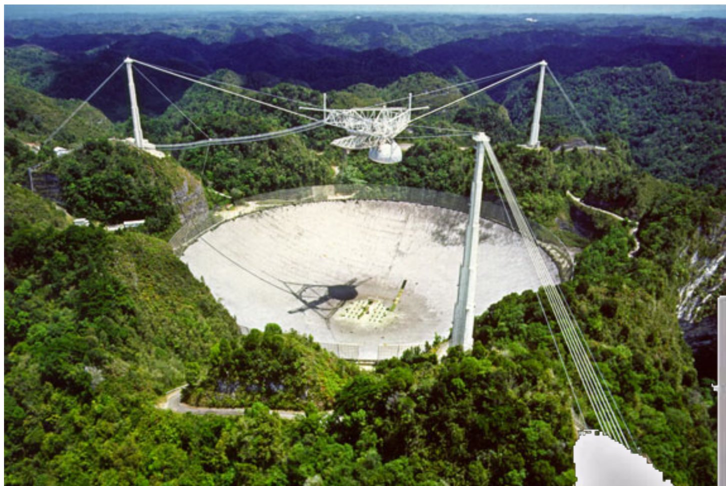
Digital Imagery

1. Digital images
    a) Acquisition model
    b) Discretisation / quantization
    c) Formalism
    d) Représentation

Digital imagery
Acquisition



Digital imagery
Acquisition – other examples



Radiotelescope

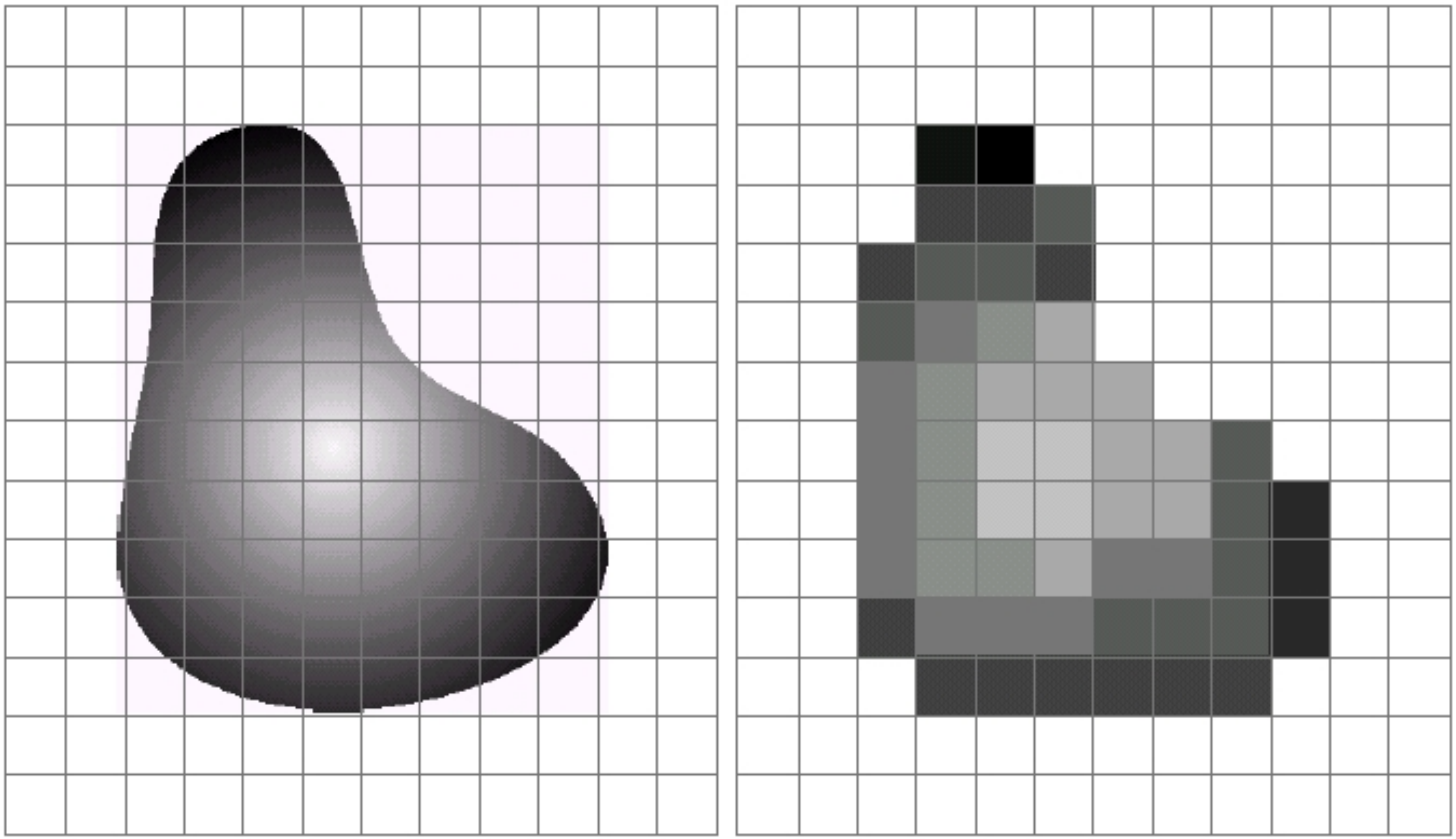
Electron microscope
(electron flow)

MRI - Nuclear
Magnetic Resonance

Digital imagery

Spatial discretisation

Pixel = Picture element

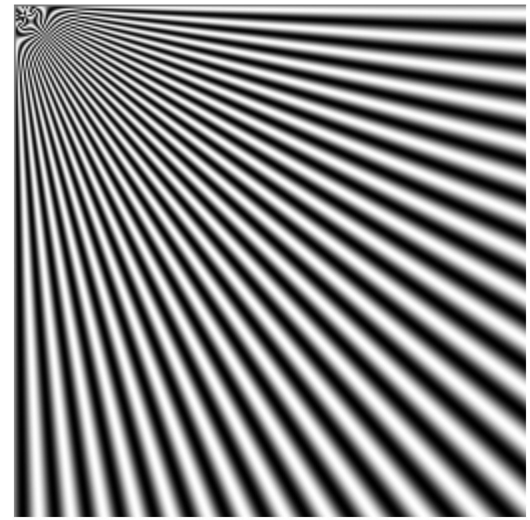


Some problems: area estimation, perimeter estimation, sub-pixelic precision

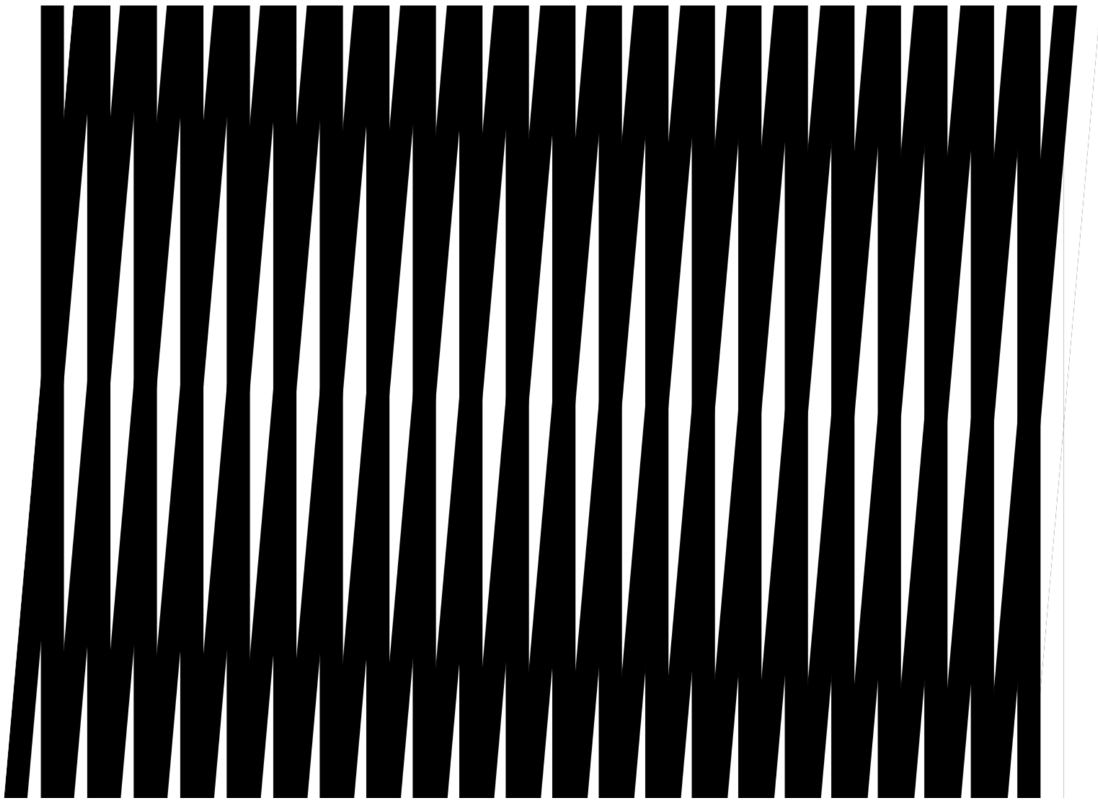
Digital imagery
Spatial discretisation

- Resolution means two different things
  - The dimension of the spatial domain spatiale,
    - ex: 1024*860 pixels
  - The size of a pixel,
    - ex: on a aerial photo, the length of a pixel can be as large as 1 meter, in the printing business, we speak in dpi (dot per inch)

Digital imagery
Spatial discretisation
Subsampling – Aliasing - Moiré



A Moiré Pattern



Digital Imagery

Grey-level quantization

$256 = 2^8$

$128 = 2^7$

$64 = 2^6$

$32 = 2^5$

$16 = 2^4$

$8 = 2^3$

$4 = 2^2$

2

Details, shading, visual quality

Digital Imagery

Formalism

- A digital image is a function

$$f : E \mapsto V$$

- Spatial domain:

$$E \subseteq \mathbb{Z}^2\text{: images 2D ou } E \subseteq \mathbb{Z}^3\text{: images 3D}$$

- Value space V:

$$\{0{,}1\} \text{ ou } [0..255]^n \text{ ou } \mathbb{R}^n \text{ ou } \mathbb{N}^n$$

  – *n* =1 : grey level image
  – n= 3 : (pseudo-)color image
  – *1<n* <20 : multibands image
  – *n>19* : hyperspectral image
- Binary image: equivalent to a set

$$F = \{x \in E \mid f(x) = 1\}$$

Digital Imagery
Formalism

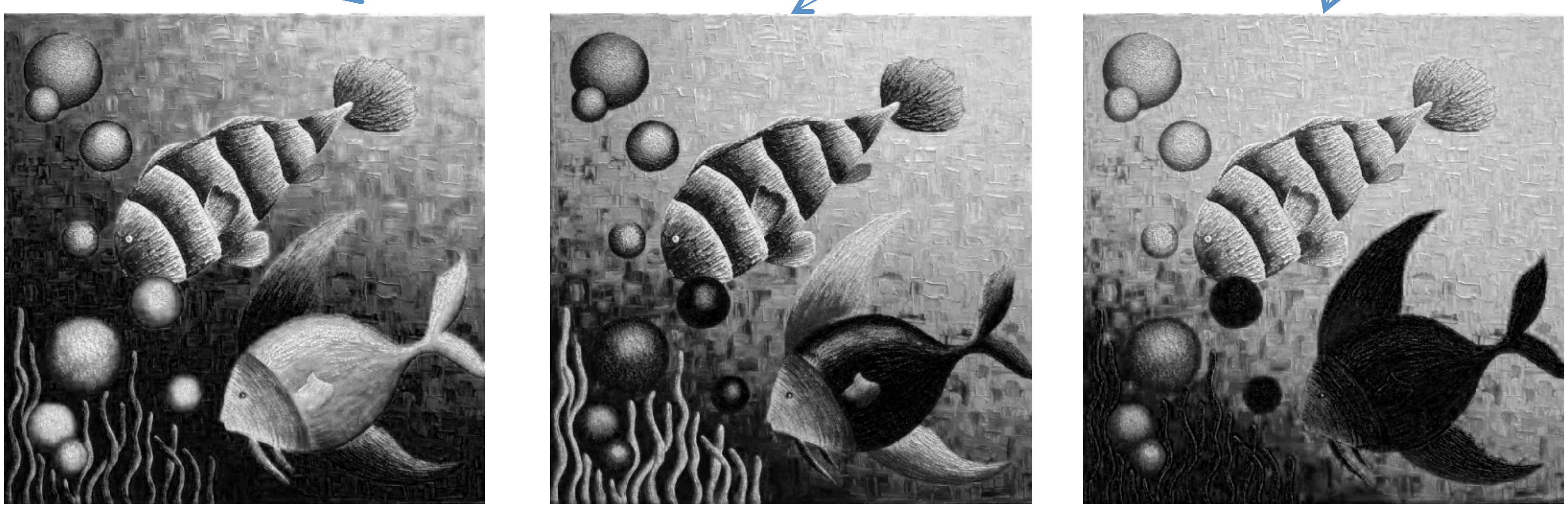
- Ex : RGB image RGB
  - RGB: Red-Green-Blue

$f : [0..511]^2 \mapsto [0..255]^3$

Red chanel

Green chanel

Blue chanel



Digital imagery
Formalism - storage

- Ex: color image, Full HD:
  - 1024 lines, 1900 columns : E=[0..1023]x[0..1899]
  - RGB color on 256 levels : $V=[0..255]^3$

- Problem: a lot of data!
  - Astronomy: 10 000 x 10 000 pixels, pixel values with double precision (64bits), 5 bands

$$\frac{10000^2 * 8 * 5}{1024^3} \approx 3.7 \text{ Go}$$

  - A video of 2 hours-length, Full HD, 25 img/sec:

$$\frac{1024 * 1900 * 3 * 25 * 60 * 60 * 2}{1024^3} \approx 978.4 \text{ Go}$$

Digital imagery

Formalism – Computation time

- We want to process a HD flow with 25 fps
- The processing needs 100 operations/pixels (linear!)
- We suppose that each operation takes one processor cycle
- What is the frequency that is necessary?

$$1024 * 1900 * 25 * 100 \approx 5\,\mathrm{GhZ}$$

- We need a specific hardware
  - Parallel computing / GPU / …

Digital Imagery
Representation

- Images are generally store into memory as matrices
- Example for a 2D image

$$\mathbf{F} = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\ a_{1,0} & a_{1,1} & \cdots & a_{1,N-1} \\ \vdots & \vdots & & \vdots \\ a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1} \end{bmatrix}$$

$$\text{avec } a_{ij} = f(x = i, y = j) = f(i, j)$$

Digital Imagery
Representation

- Be careful: the processing order is not neutral on algorithmic performance
- On the same image:

```
for(int x=0;x<image.xdim;x++)
        for(int y=0;y<image.ydim;y++)
                image.getPixelXYDouble(x, y);
```

Execution time: 1000 ms

```
for(int y=0;y<image.ydim;y++)
        for(int x=0;x<image.xdim;x++)
                image.getPixelXYDouble(x, y);
```

Execution time: 200 ms

Inverting the loop order has some importance!