IMC5-1IA (image analysis).

Laurent Najman
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

Image sequence (video)

Color
Images

Biology – Medical Examples:

Microscopy (blood)

X-Ray

Fonctioanal MRI (3D+t)

MRI(3D)
Images?

Teledetection, Examples:

Radar

Sonar

Hyperspectral

Lidar
Images?

Astronomy
(Galaxy in UV)

Physics, Examples:

Electron microscopy
(snowflakes)

Radar interferometry
(glacier)

Bull chamber
(particule collision)
Images?

Gas burner (thermal power plant)

Industrial Examples:

Aluminium

2D Bar codes

Quality control on bottles
Introduction

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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:

• Deblurring:
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
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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:
  - ImageMagick : [http://www.imagemagick.org](http://www.imagemagick.org)
  - Pink: [http://pinkhq.com](http://pinkhq.com)
Software programming 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://pinkyq.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 programming software

• Chaining processing is simple

• More difficult to begin with

• Allows complex operations

• A few examples:
  – Visiquest (ex-Khoros)
  – Labview
  – NeatVision
Some references

- 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 – 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

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

\[ f : [0..511]^2 \rightarrow [0..255]^3 \]
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
    \[
    \frac{10000^2 \times 8 \times 5}{1024^3} \approx 3.7 \text{ Go}
    \]
  – A video of 2 hours-length, Full HD, 25 img/sec:
    \[
    \frac{1024 \times 1900 \times 3 \times 25 \times 60 \times 60 \times 2}{1024^3} \approx 978.4 \text{ Go}
    \]
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?

\[1024 \times 1900 \times 25 \times 100 \approx 5 \text{ GHz}\]

• We need a specific hardware
  – Parallel computing / GPU / ...
Digital Imagery
Representation

• Images are generally stored in memory as matrices

• Example for a 2D image

\[
F = \begin{bmatrix}
    a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\
    a_{1,0} & a_{1,1} & \cdots & a_{1,N-1} \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1}
\end{bmatrix}
\]

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:

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

Execution time: 1000 ms

```java
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!