Management of imprecision and uncertainty in image processing

« What men really want is not knowledge but certainty. »
Bertrand Russel

Road book

Once upon a time the imprecision, the uncertainty …

- Introduction
- Problematics
- Imprecision and uncertainty
- Examples

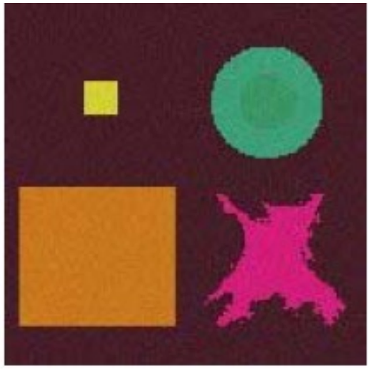
Introduction

Outline

Usually, an image is considered as a collection of regions.

One way for segmenting images is to use clustering techniques.
In this kind of approach, the aim is to analyze the organization of the data (pixels for an image).

Developped algorithms consist in finding the most relevant partition of the data in an appropriate space of representation (*i.e.* not the original image space). Then, such techniques first used a transformation to go from the image space in (most frequently) a characteristic space or space of the image features.

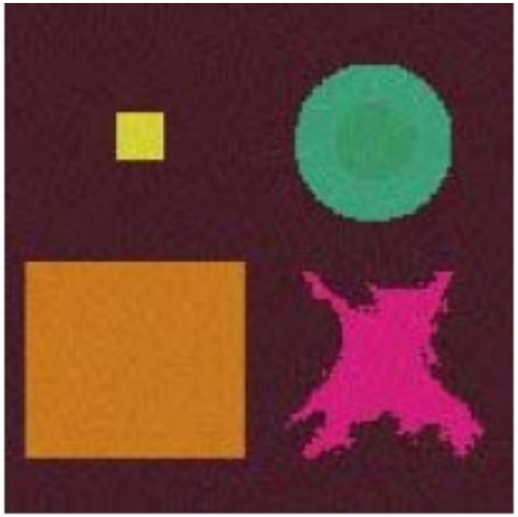


Image

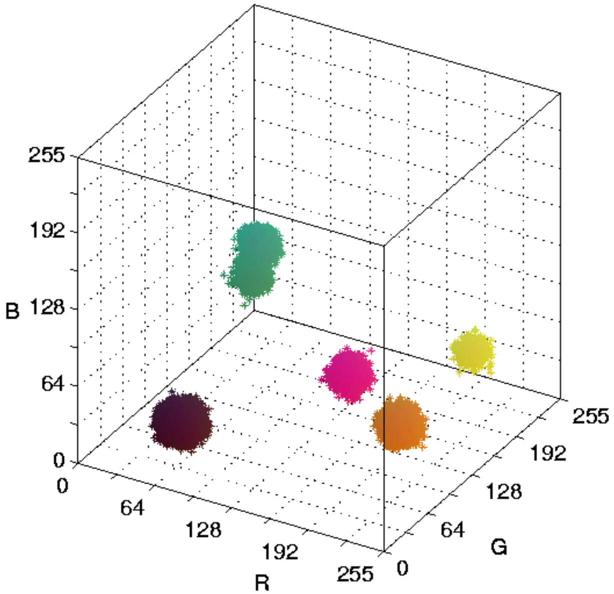
Introduction

Principle

The main idea of the clustering techniques is to analyze the pixel distributions in an appropriate space.
For instance, the RGB color space for color image.
Then the first step of a clustering process is to go from the image space in a space of characterictics or features.
In this kind of approach, a cluster is assimilated to a region (but the connexity properties are lost)



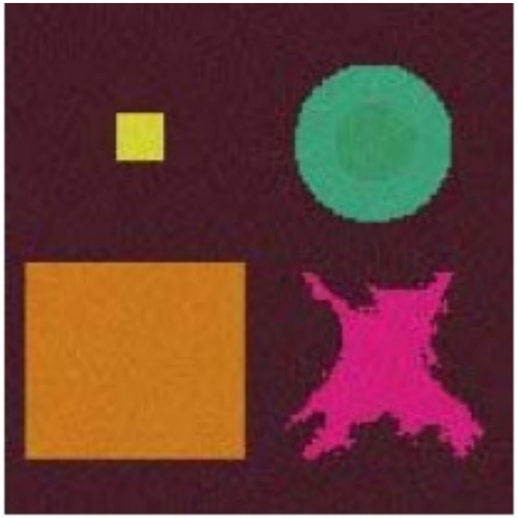
Image



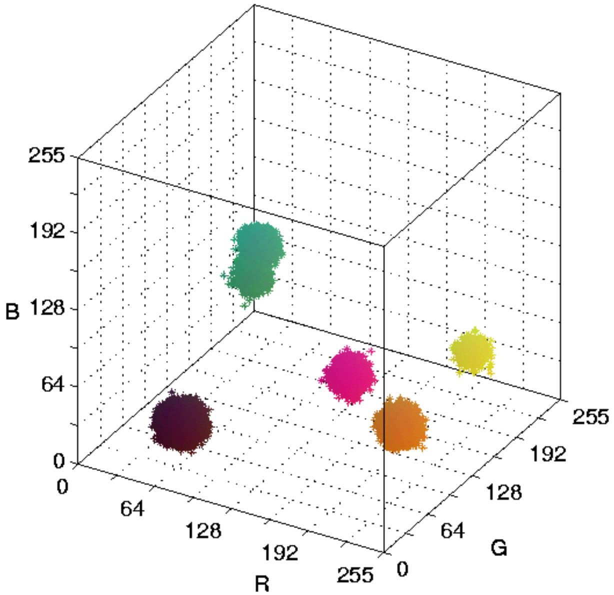
RGB color space

Introduction

Colour image segmentation based on clustering techniques



Image



RGB color space

An image is generally considered as a collection of regions.

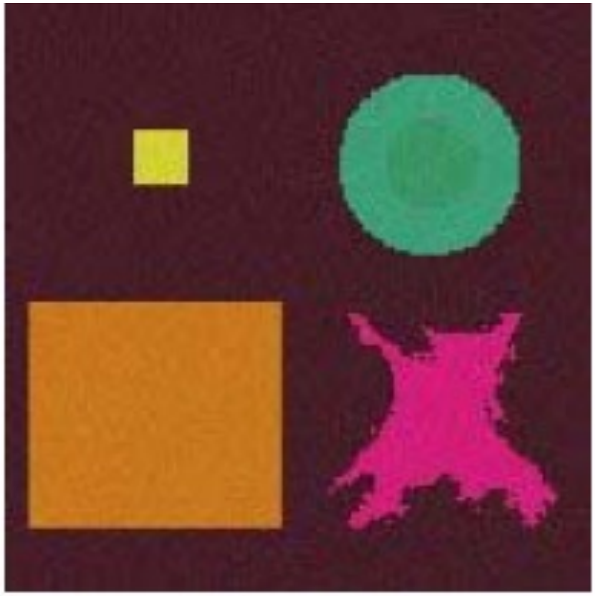
But:

- It is not easy (most of the time) to determine the number of regions.
- It is not easy (sometimes) to assign a pixel to a cluster with a high level of certainty.

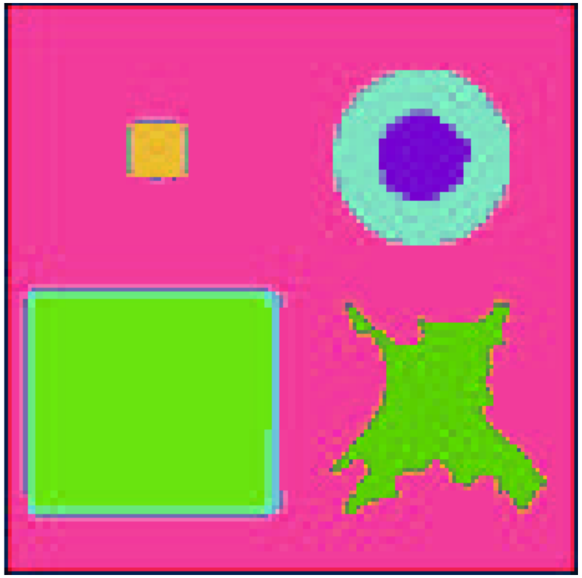
Introduction

Colour image segmentation based on clustering techniques

In a « perfect » world !!!



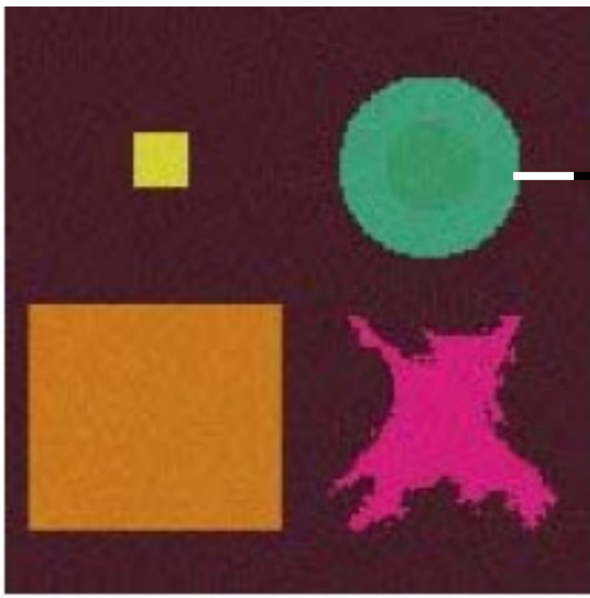
Image



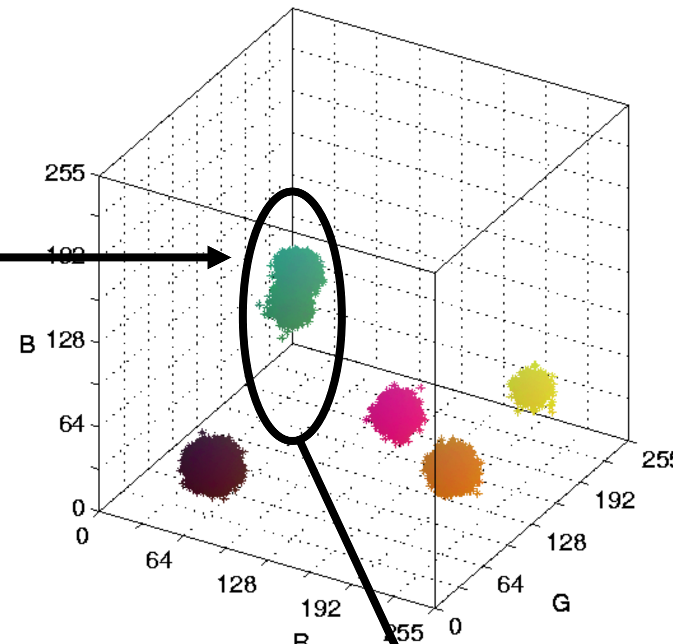
Expected result after clustering

Introduction

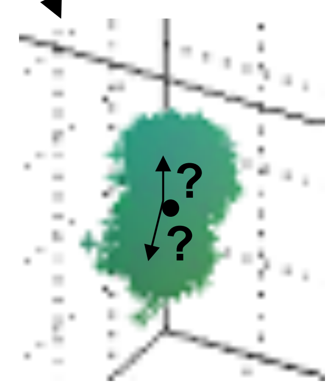
Colour image segmentation based on clustering techniques



Image



RGB color space

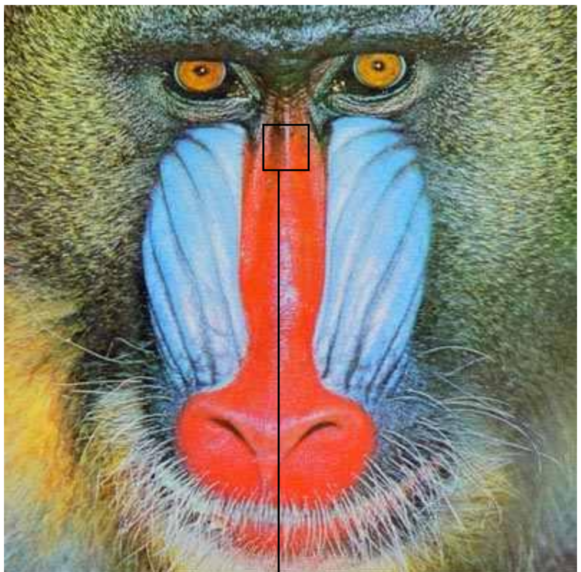


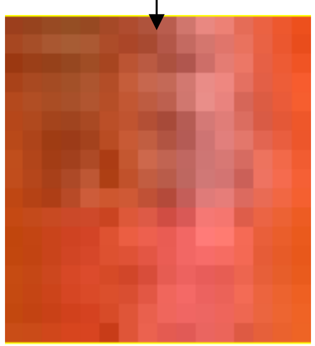
In a « perfect » world … a pixel belongs or does not belong to a cluster, but… is there an easy way to achieve a sure and good result ?

Introduction

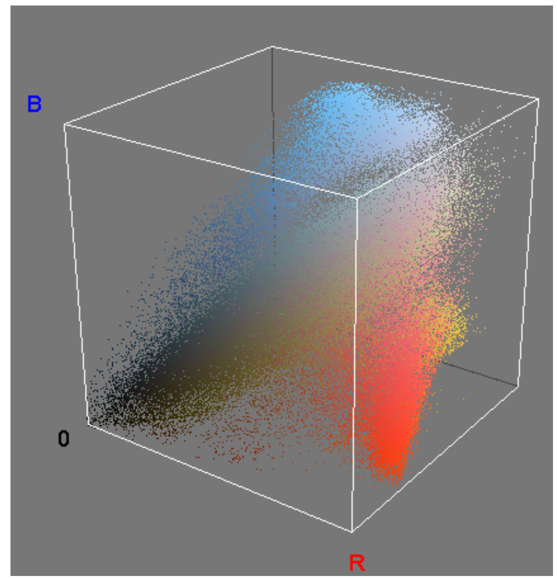
Colour image segmentation based on clustering techniques

Image





RGB color space

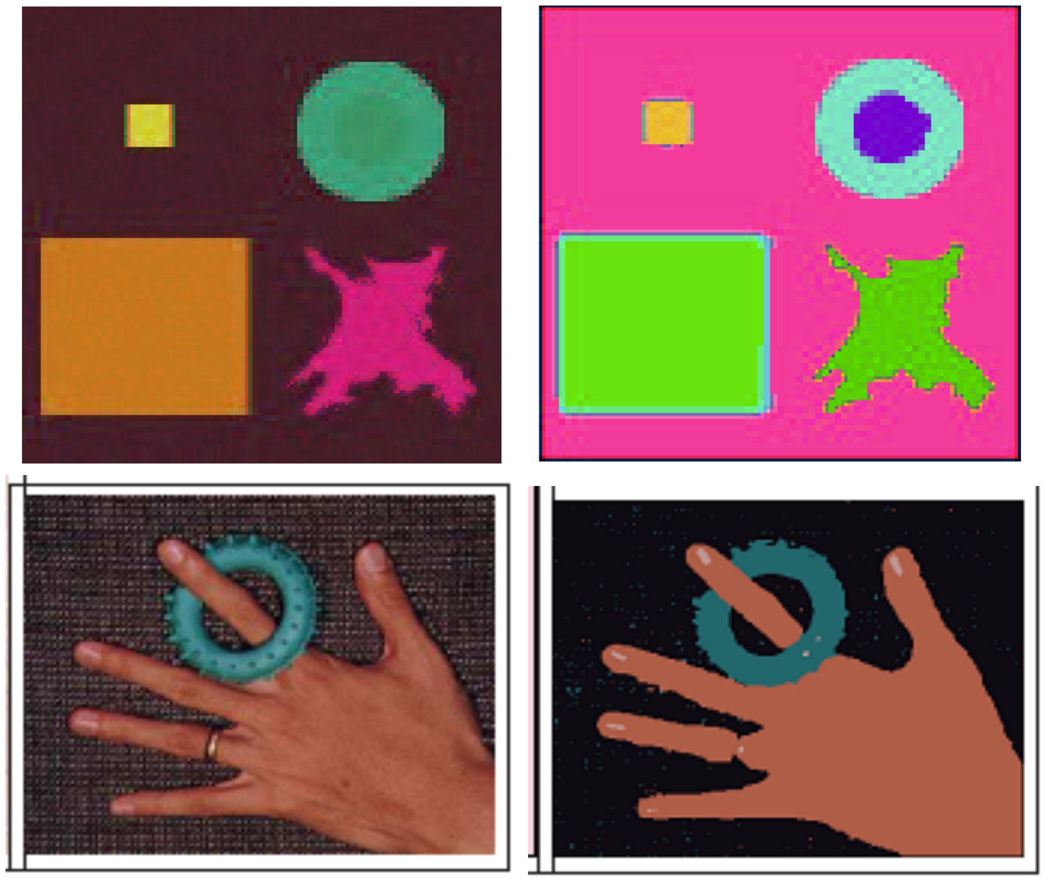


Where are the clusters?

Mixture? Not homegeneous region?

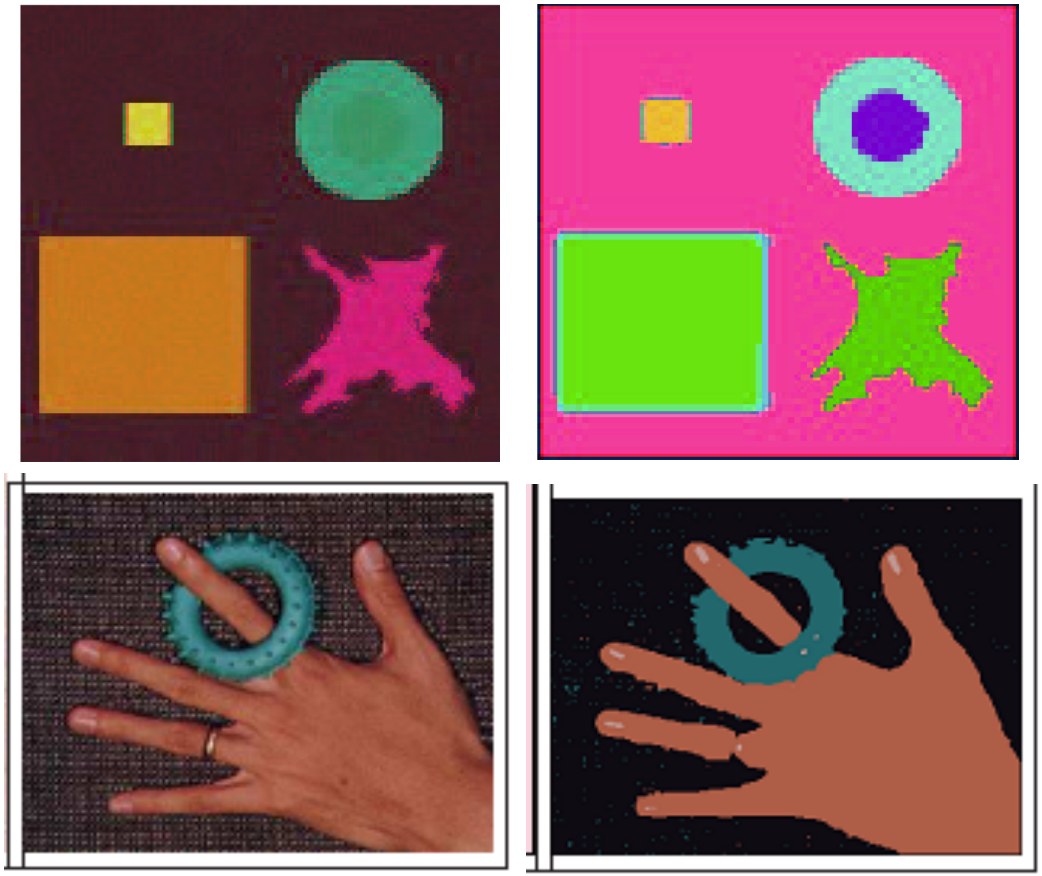
Introduction

The aim of segmentation techniques is to obtain a partition of an image in significative regions with a high level of certainty (a sure and robust decomposition).



Introduction

The clustering methods are based on the quantification of the membership degree of a pixel to a cluster (considered as being a region).



Introduction

Some questions about clustering techniques

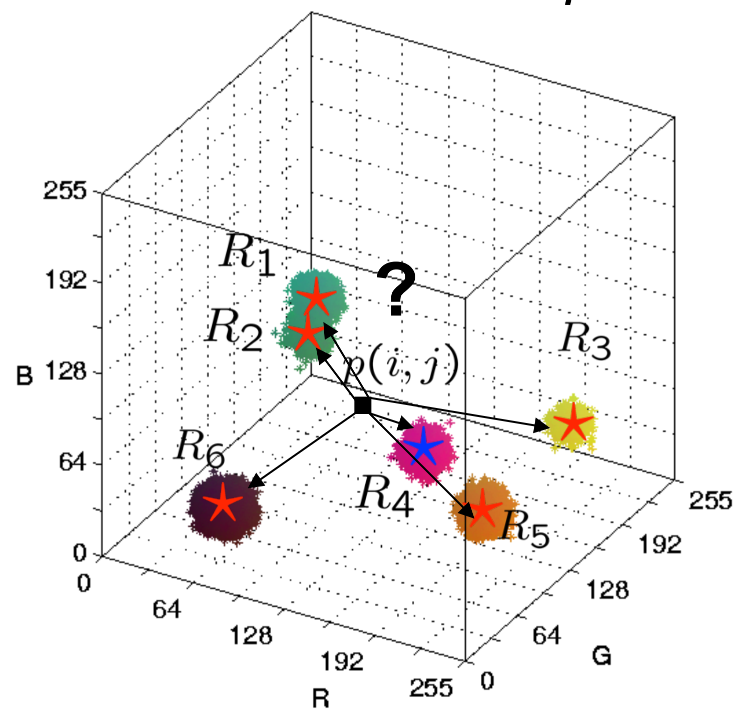
- How to determine the number of cluster?
- The used technique determine the most relevant organization of the data without any *a priori* information (unsupervised methods) or some *a priori* information are available to help the algorithm (more or less supervised)?
- How to ensure a good and sure assignment of a pixel to a particular cluster (that is to say to a region)?
- How taking into account the imperfection of the data of interest?
- And many other questions…

Introduction

A focus:

What to do with data which are not close to a specific cluster and which could be assigned to two or several clusters (uncertainty and imprecision)?

Color distribution of an image in the RGB color space



⋆: center of gravity of a cluster

Characteristics of the data

Imperfection of the data

- Perfect informations (data) and perfect algorithms do not exist.
- Different aspects :
  - imprecision
  - uncertainty
  - delay
  - missing data

Characteristics of the data

Example



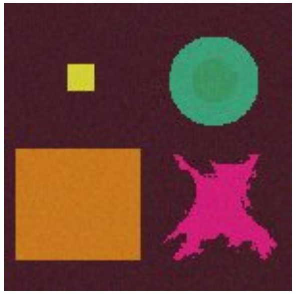
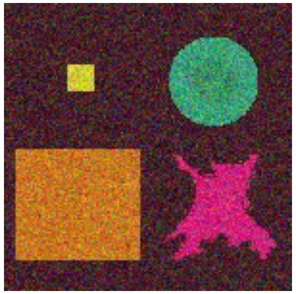



Image: often corrupted by noise
☞ *Acquisition conditions, electronic devices*

Consequences:
- On colours for example.
- Regions are not homogeneous, textures are corrupted.
- Contours are not well defined.
- …

so…. **imprecisions and uncertainties**

Consequences for the data processing and results:
- Risk of errors
- Interpretation can be falsified

Characteristics of the data

The world is imperfect….the data too !

«I am approximately 1m80 tall!» Imprecision

«Maybe It will rain tomorrow!» Uncertainty

«Maybe it will rain very much tomorrow!» Both to intensify the problem !

Characteristics of the data

Imprecision, uncertainty

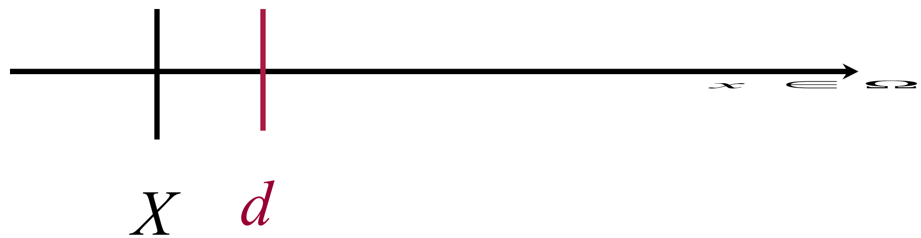
- One can decrease the uncertainty of a proposition by increasing its imprecision.
  - Example :
  - « The prof's height is *probably* upper to 1.70 m ».
  - ☞ « The prof's height is *surely* upper to 1.50 m ».
- Other kinds of imperfection of the information : *vagueness, fuzzy*
  - *Example :* « The prof is tall ».
  - Needs an extension of the theory of sets:

    ☞ *Fuzzy set theory*.

Characteristics of the data

Imprecision

- Estimate of the difference between the measure *d* given by a sensor and the true unknown value *X* to measure.



Exemples :

«My height *X* is about 180cm!.»

« The height *X* is *180cm* more or less *2cm. »*

It means :

« The true value of *X* is in the range *[178cm ; 182cm]. »*

- But also: «Prof. is tall or medium » is translated as

$$\text{Prof} \in \{\text{"Tall" OR "Medium"}\} = A = \{\text{"Tall"} \cup \text{"Medium"}\}$$

$$Card(A) = 2$$

Characteristics of the data

Uncertainty

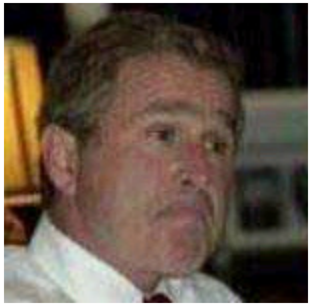
- Doubt about the reality of the different hypotheses ω_i in the set Ω *(confidence).*

Examples :

«Maybe it will rain tomorrow!»

« The probability that the observed man is G.W.B. is equal to 90%. »

(it could be a double !)



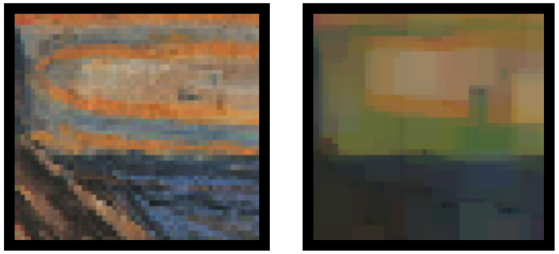
Characteristics of the data

Different kinds of imperfection:

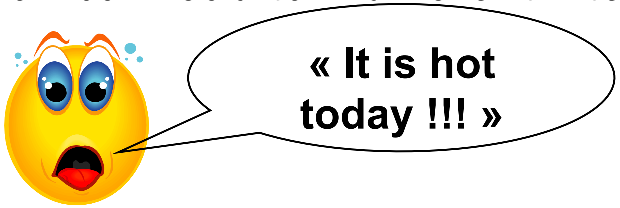
- Imprecision: translates the lack of accuracy of the knowledge (in quantitative terms).

- Uncertainty: translates the degree of conformity of the information with the reality.

- Incompleteness: absence of information brought by a source on some aspects of the problem.



- Ambiguity: supplied information can lead to 2 different interpretations.



- Conflict : several information lead to contradictory interpretations.

Vocabulary

Information sources

- Physical sensors:
  - Image sensors: camera, telemeter, radar, MRI, ultrasound.
  - Signal sensors : temperature, speed, acceleration…

- Logical sensors:
  - Modules (algorithms) of signal processing.
  - modules (algorithms) of image processing.

- *A priori* knowledge:
  - objects and their characteristics.
  - observed scene (maps, atlas...).
  - Evolution rules (when the temperature increases, the ice melts).
  - ...

«Raw material» and «manipulated products »

Data

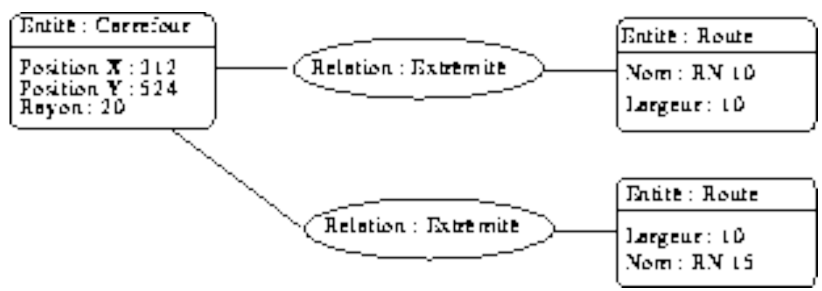
- **Numerical measurements:**
  - Distance.
  - Grey level (image).
  - Signal duration …

- **Symbolic data:**
  - Dangerous situation.
  - Presence of a lesion.
  - Offensive target...

«Raw material» and «manipulated products »

Data

- **Numerical data :**
  - Absolute value (lenght, temperature)
  - Relative value (%)
  - ☞ *The most frequent ones*
- **Ordinal data :**
  - Scale of salaries (small, medium, high)
  - ☞ *one can define an ordering A<B<C*
- **Nominal data :**
  - Colour of eyes (brown, blue)
  - ☞ *Only possible comparisons A=B or A≠B*
- **Binary data :**
  - Presence or absence of a characteristic, sex,…
  - ☞ *particular case of ordinal or nominal data*
- **Symbolic data :**
  - IGN map



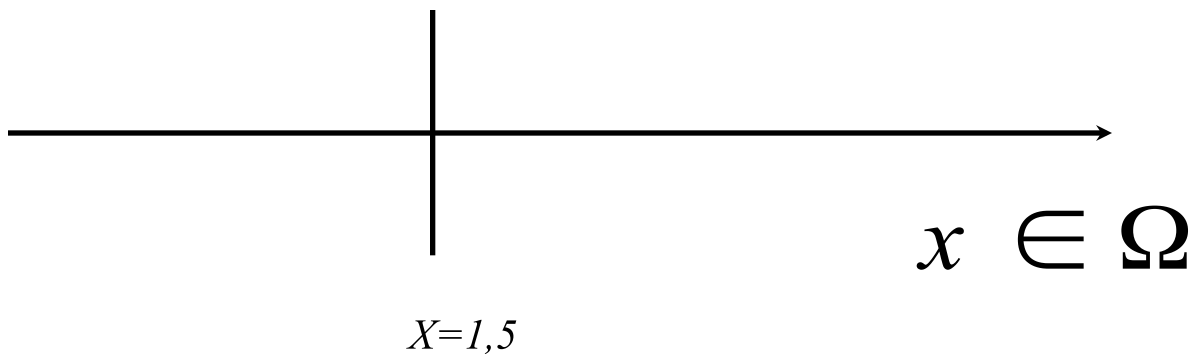
Relation between entities

Remark: possibility of missing data

«Raw material» and «manipulated products »

Numerical informations

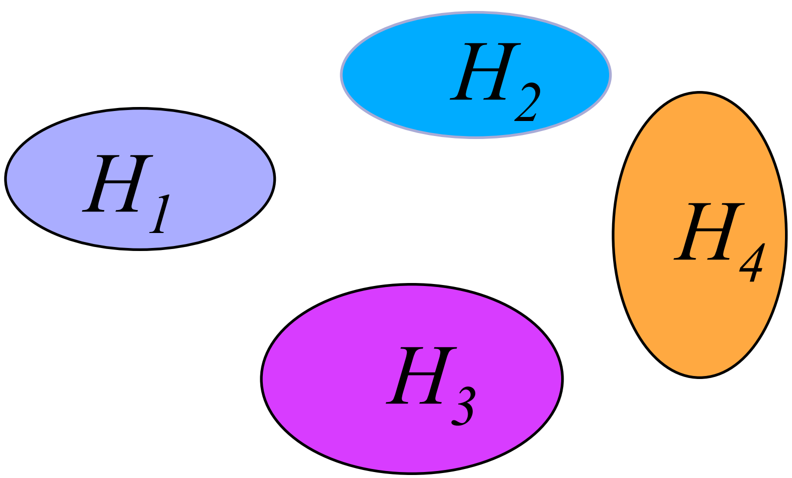
- informations given by numbers.
- Orderly definition space *Ω*.
- *example :* the width of the car is *1,5m.*



«Raw material» and «manipulated products »

Symbolic information

- Information given by symbols, propositions, rules.
- Non-orderly definition space Ω.



- H_1 : the object is a car
- H_2 : the object is a truck
- H_3 : the object is a motocycle
- H_4 : the object is a pedestrian

«Raw material» and «manipulated products »

Hypotheses and propositions

- **Hypotheses** ω_i

  Elements of the definition space (frame of discernment)

  $\Omega = \{\omega_1, \omega_2, \ldots, \omega_n\}$ (a set of image regions for instance)

☞ *Singletons (exclusive, exhaustive)*

- **Propositions *A_i***

  Elements of the powerset 2^Ω (set of the parts of *Ω).*

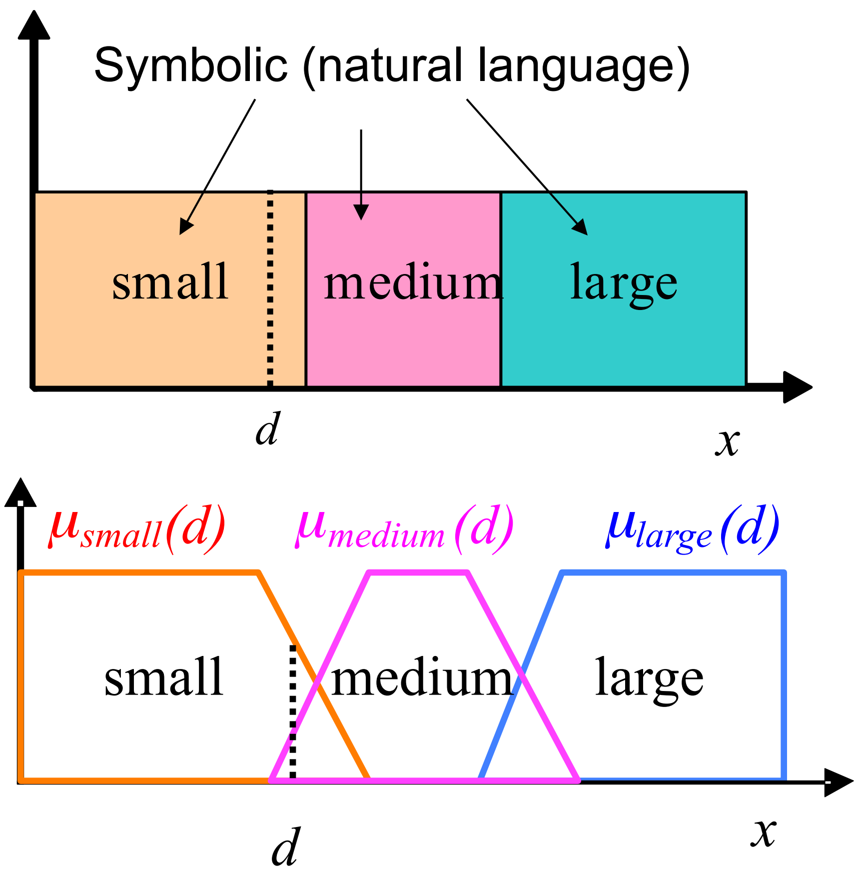
  $$2^\Omega = \{\emptyset, \omega_1, \omega_2, \ldots, \omega_n, \omega_1 \cup \omega_2, \ldots, \Omega\}$$

Link with the theory of sets

- Logical OR : union $\cup$
- Logical AND : intersection $\cap$
- Proposition : union of hypotheses ≡ OR between the hypotheses $\left\{\omega_i, \omega_j\right\} \equiv \omega_i \cup \omega_j$ denoted $\left\{\omega_i, \omega_j\right\}$ or ω_{ij} or $\omega_{i,j}$

Notions of sets

Different concepts



Classical sets

Fuzzy sets

The management of the imprecision and the uncertainty

Uncertainty, imprecision

- Set Ω : set (continuous or discret) of hypotheses, possibilities, possible responses to a question.
- y= the correct response.
- The value of y may be
  - known ($y=\omega$, $\omega \in \Omega$).
  - unknown ($y \in \Omega$).
  - partially known (most frequent case).
- *Problem* : how to model partial knowledge and how to use them in a reasoning?

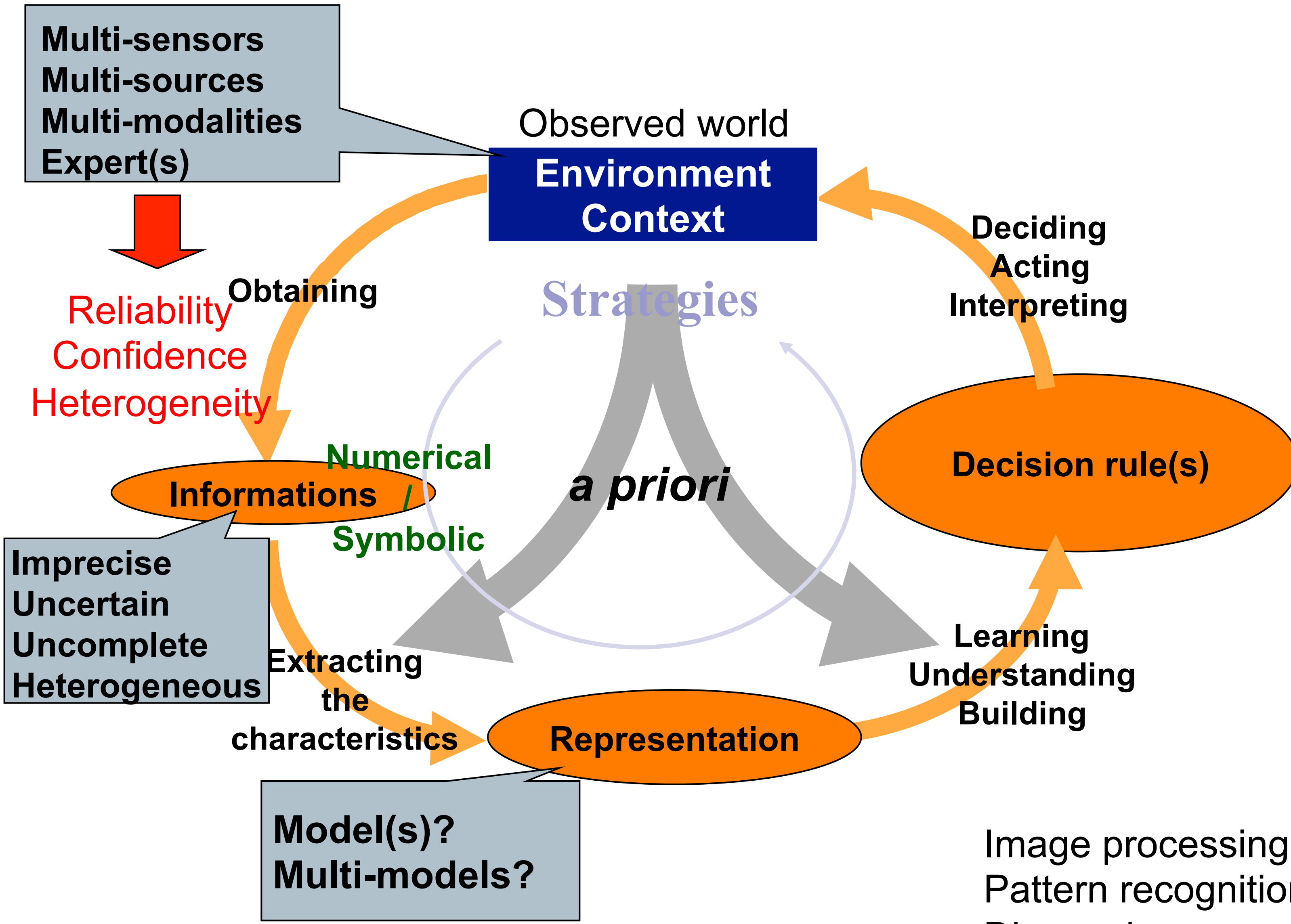
The management of the imprecision and the uncertainty

Uncertainty, imprecision

- **General model :**
  - Piece of information = (A $\subseteq \Omega$, confidence).
  - A= set of possible values for *y.*
  - Confidence : confidence in the fact that $y \in$A (0 ≤ confidence ≤ 1).

- **Two main kinds of imperfections of the information:**
  - *imprecision* : card(A)>1.
  - *uncertainty* : non total confidence (doubt) in the trueness of the information.

From information to decision



Probabilistics and non probabilistics methods

Image processing,
Pattern recognition,
Diagnosis,
Fuzzy control

Available theories to manage imperfect data or information

- **3 theories :**
  - Probability theory (frequentist and subjective).
  - Possibility theory (fuzzy sets theory).
  - Belief function theory (theory of evidence, Dempster-Shafer's theory).

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Note

The main part of the course concerns the use of fuzzy logic approaches and their application to image processing

This is the end of this part!