

Objectivity and subjectivity

in the analysis of 3D movement data

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Polemic aspect of the paper

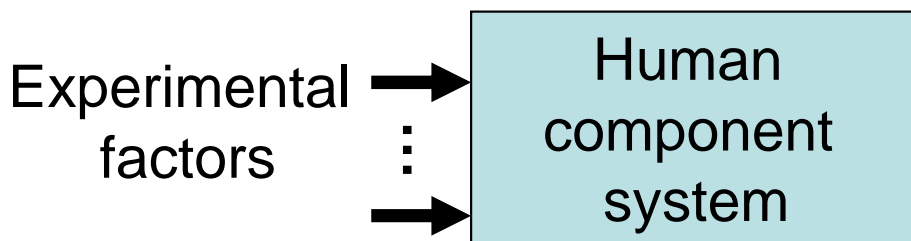
*Definition of **Subjectivity** :*

« ... the quality or condition of viewing things exclusively through the medium of one's own mind ... » (Oxford English dictionary)

- I. The aims of the data analysis
- II. The 5 stages of the data analysis
- III. The first stage : data characterization
- IV. The subsequent analysis
- V. Conclusion

I. The aims of the data analysis :

The case of the experimental design



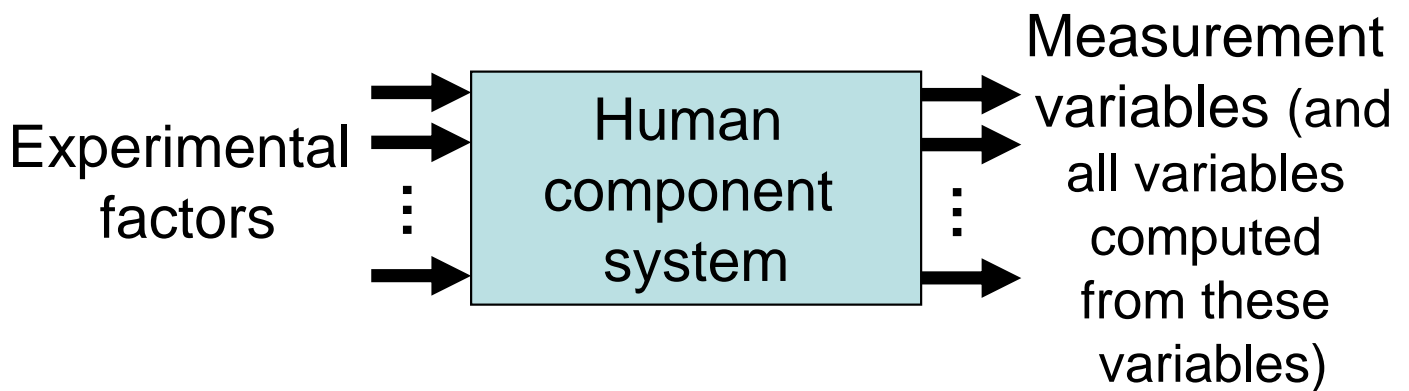
One main feature :

****the scale***

- quantitative (e.g. speed in the lifting task machine)
- qualitative
 - ordinal (e.g. 3 age categories)
 - nominal (e.g. sex)

I. The aims of the data analysis :

The case of the experimental design



Three main features :

* ***the scale***

* ***the origin***

- *the Human component => subjective data*

- *non Human component => objective data*

• ***the imperfections***

- *human error*

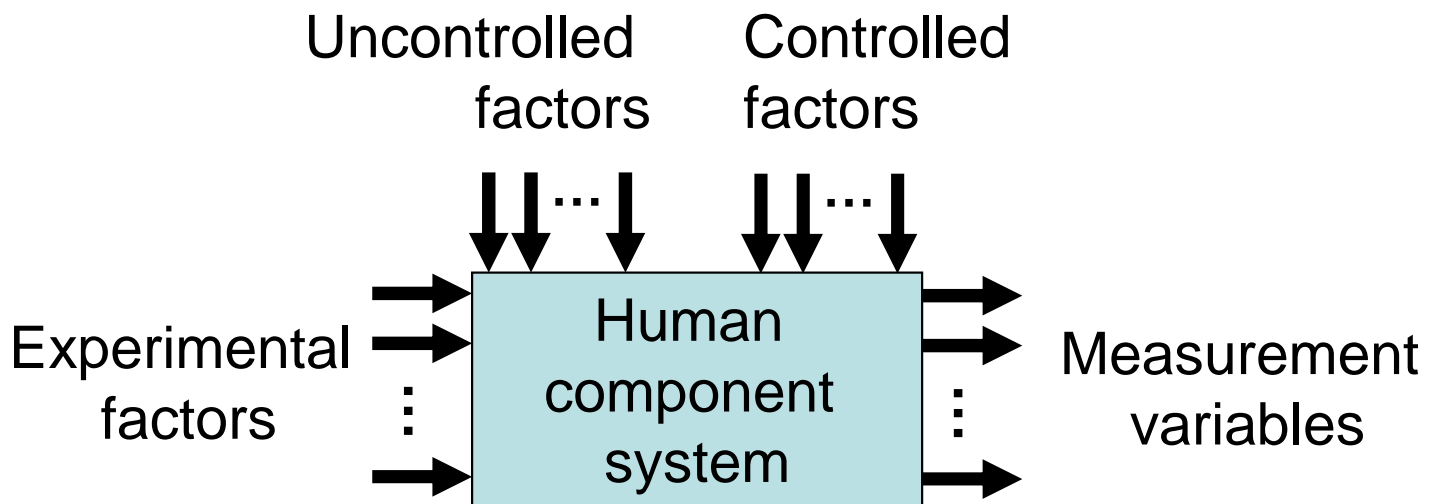
- *uncertainty*

- *calibrating*

- ...

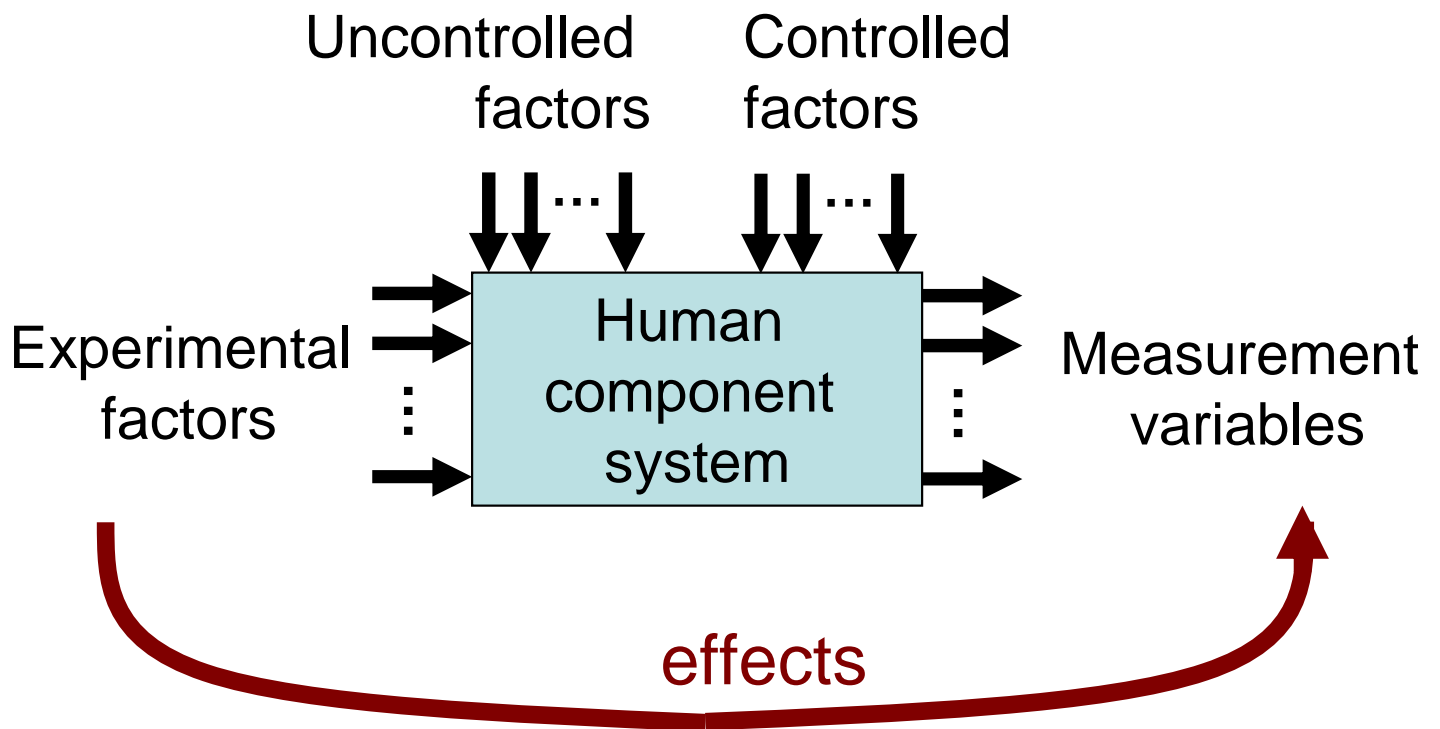
I. The aims of the data analysis :

The case of the experimental design



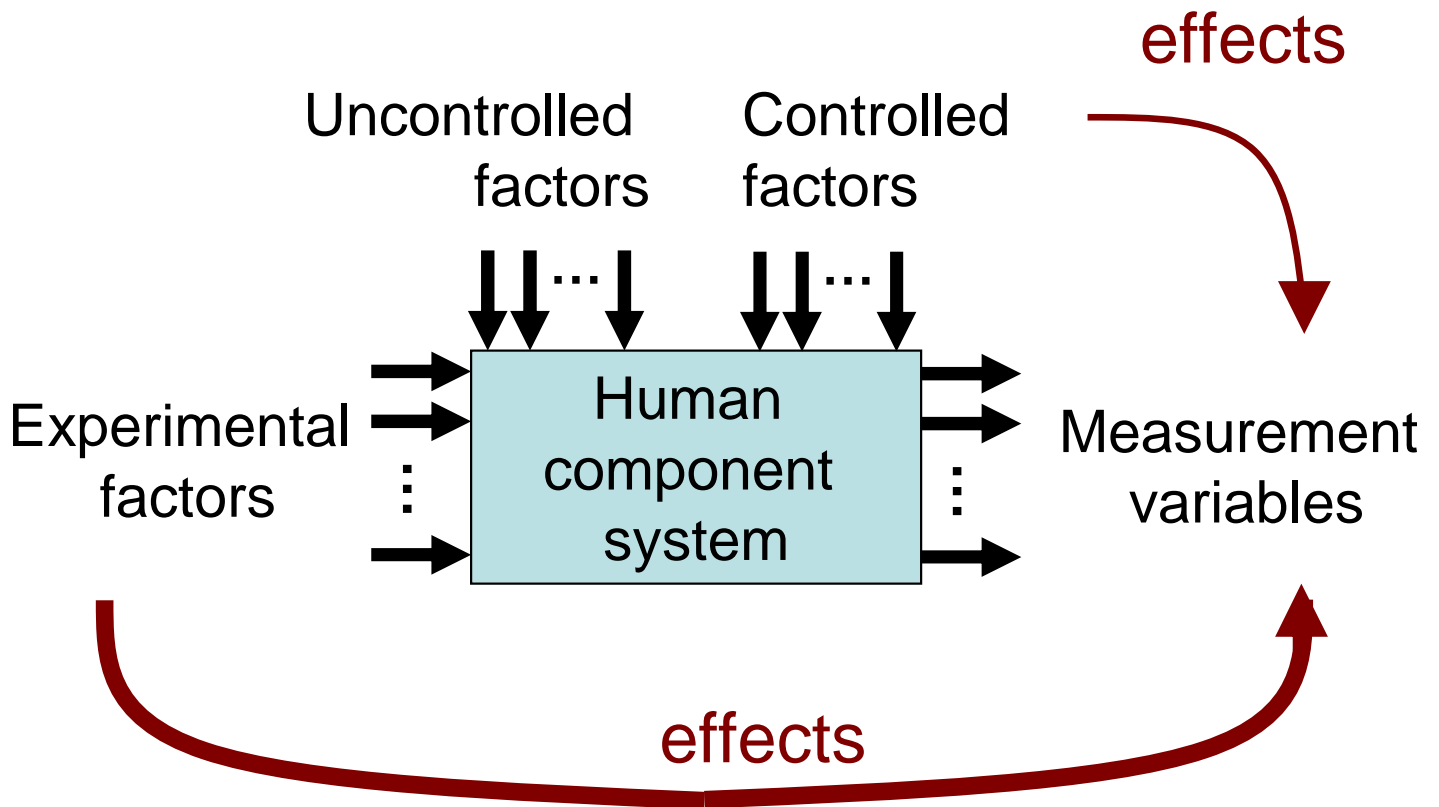
I. The **aims** of the data analysis :

The case of the experimental design



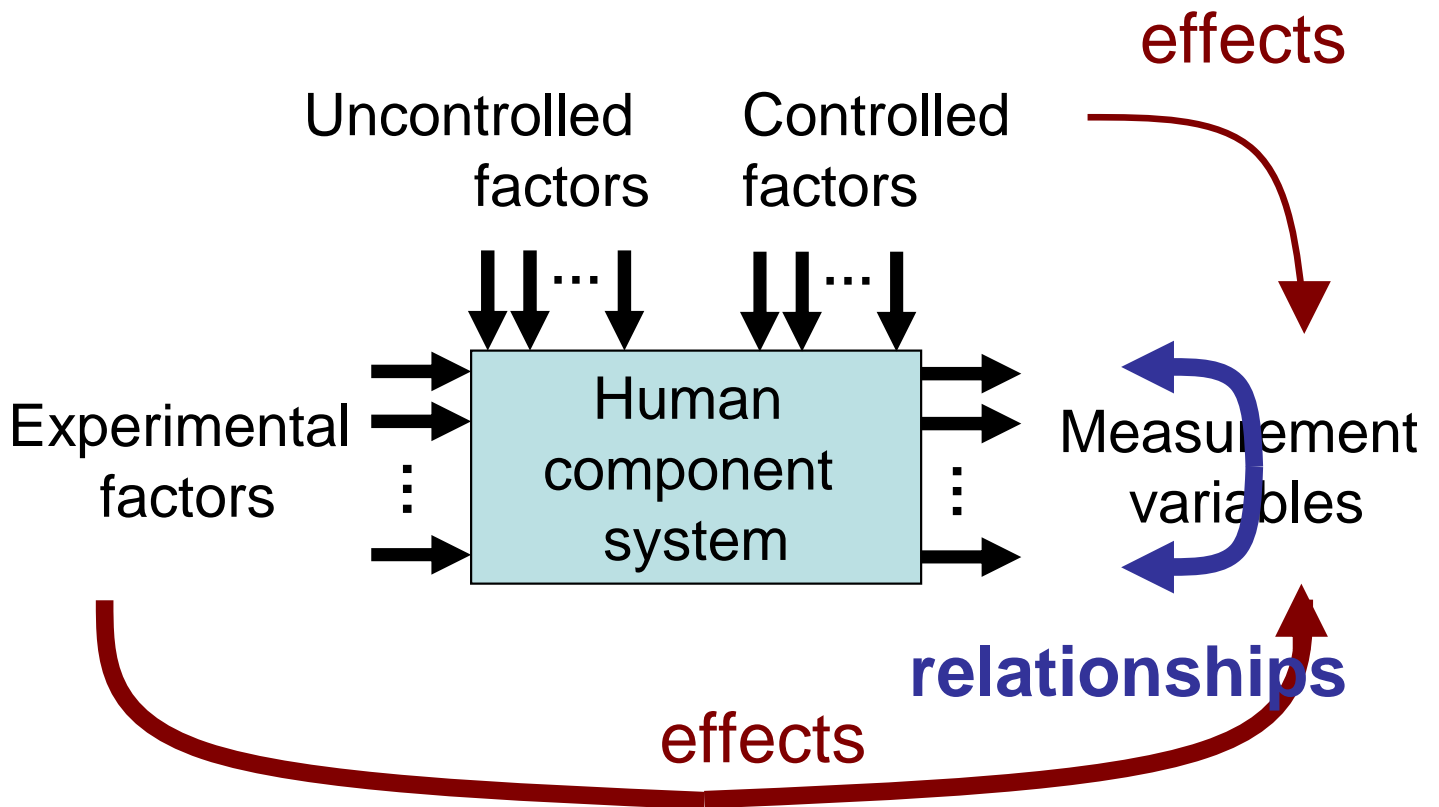
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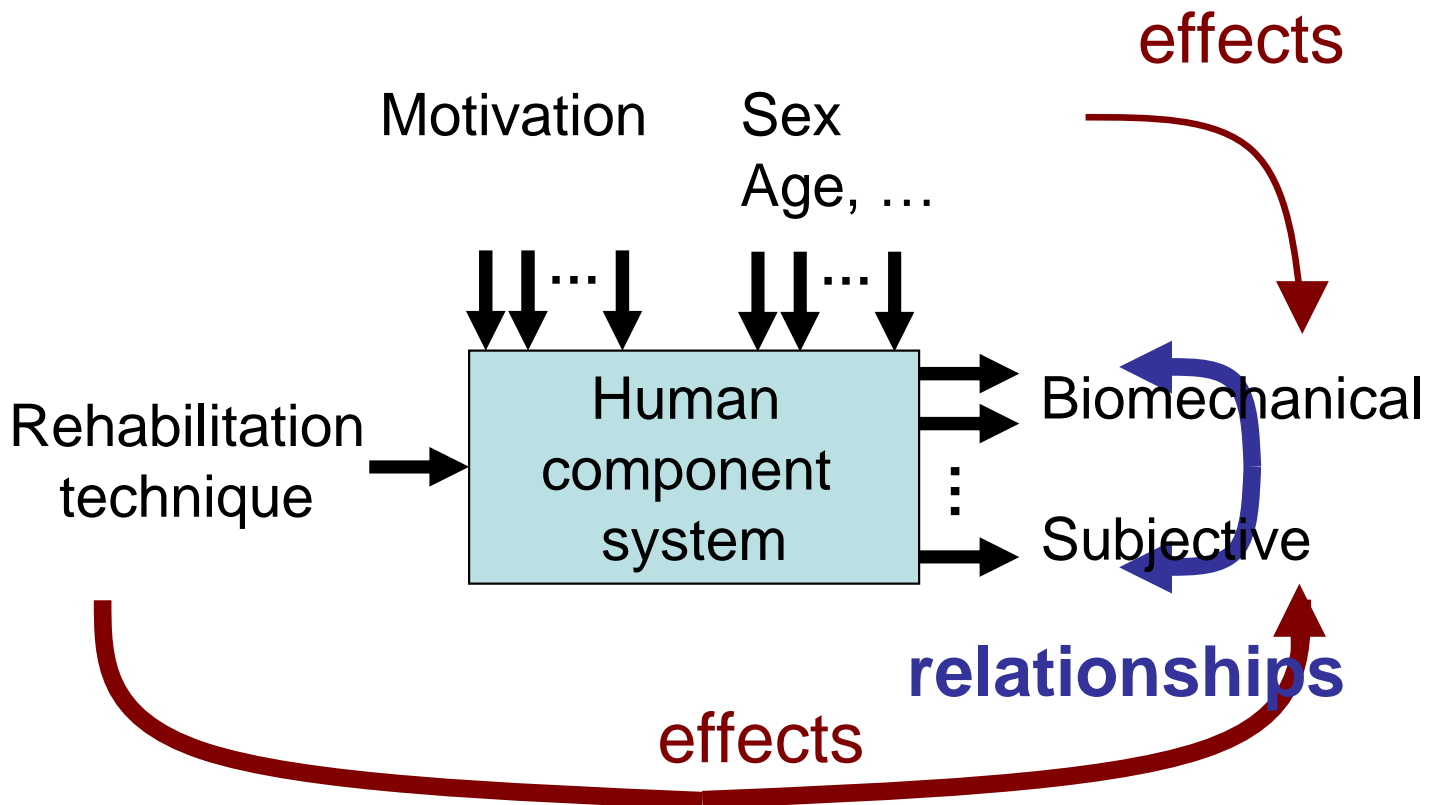
I. The aims of the data analysis :

The case of the experimental design



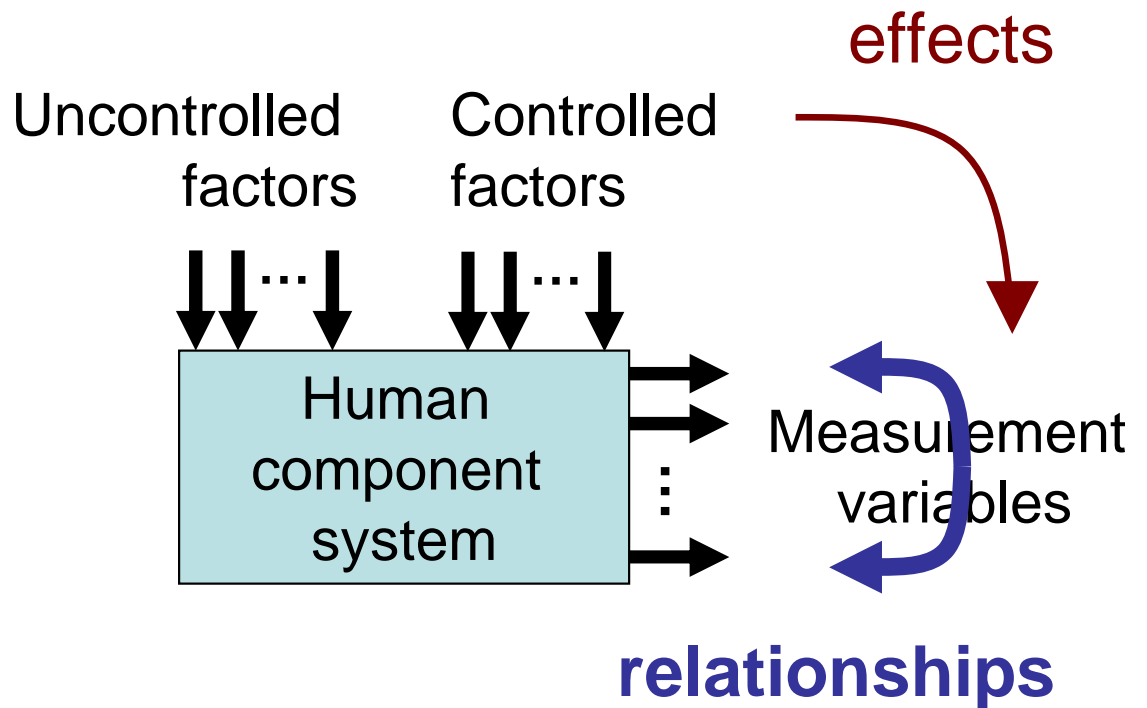
I. The aims of the data analysis :

Example : gait



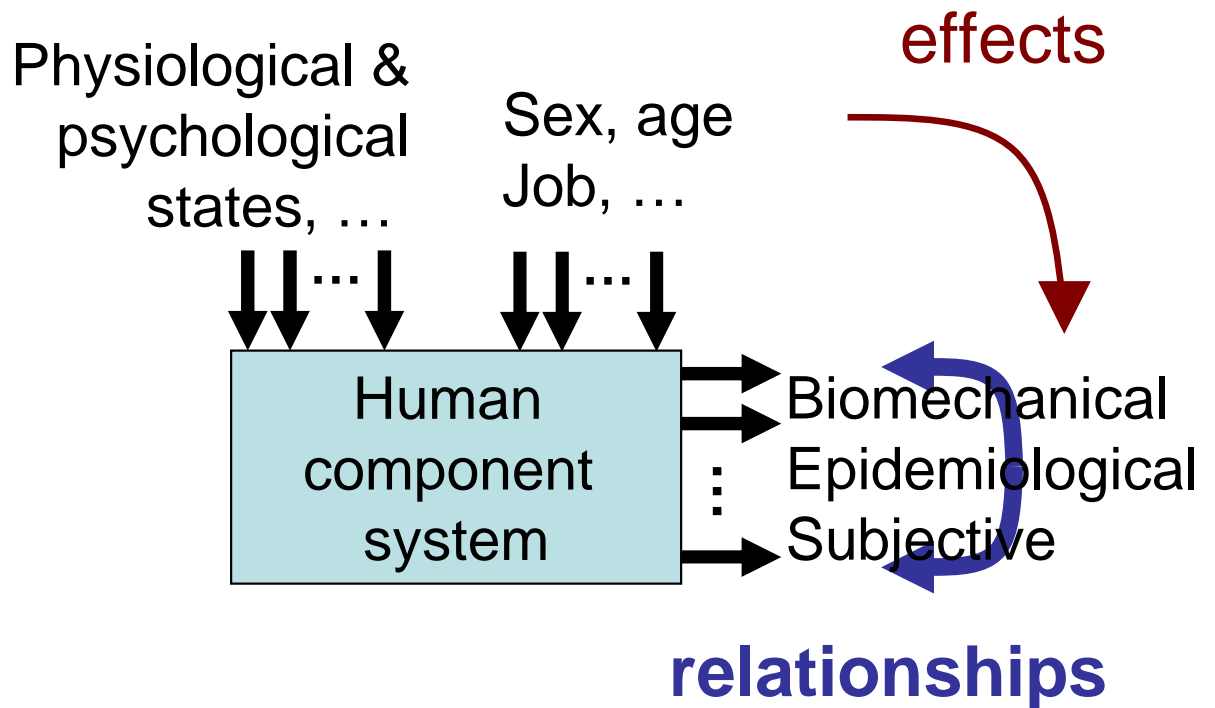
I. The aims of the data analysis :

The case of the observational design



I. The **aims** of the data analysis :

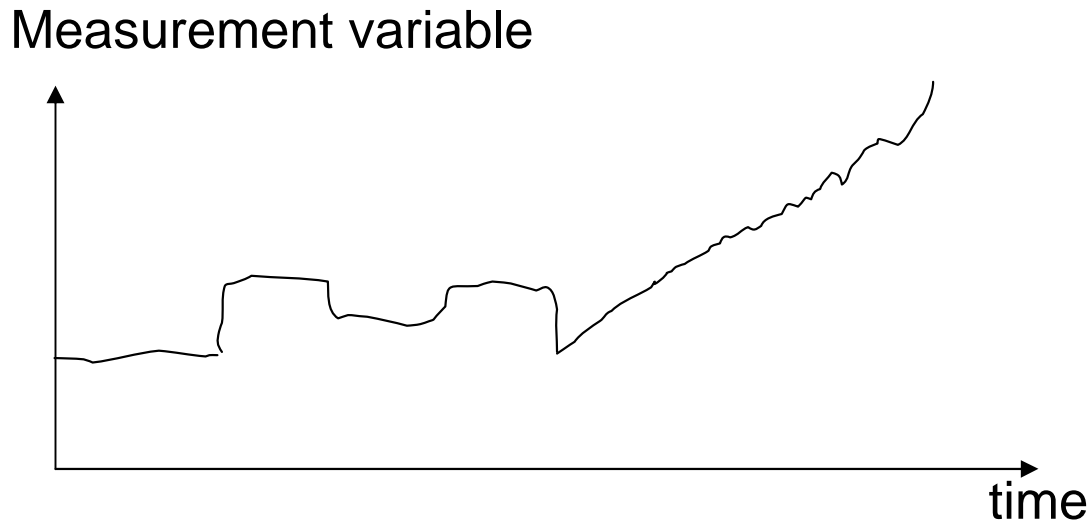
Example : carpal tunnel syndrome



- I. The aims of the data analysis
- II. The 5 stages of the data analysis**
- III. The first stage : data characterization
- IV. The subsequent analysis
- V. Conclusion

II. The 5 stages of the data analysis :

1) *data characterizing*

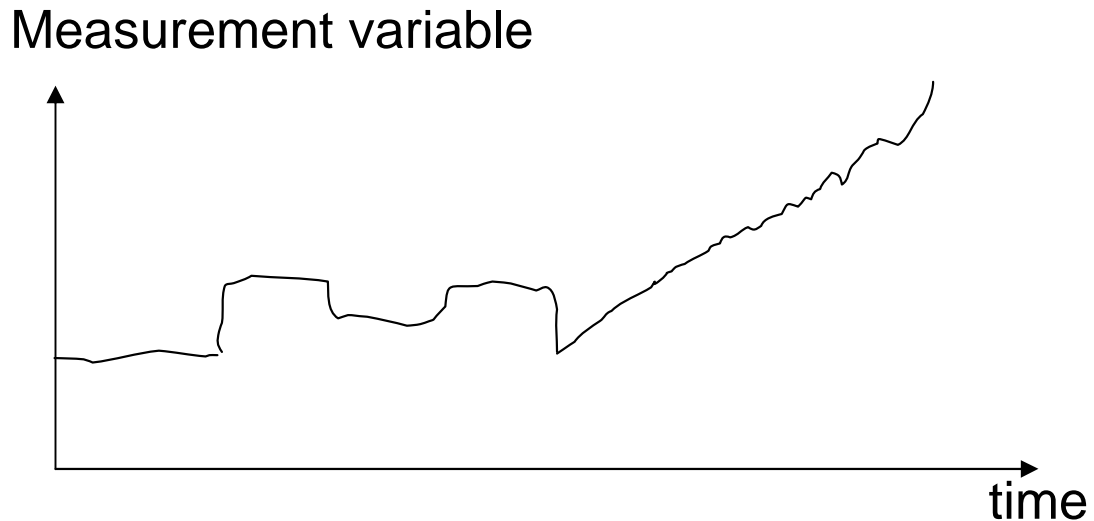


Main characterizing methods

- * **Methods yielding one or two global (overall) indicators**
 - measure of location (arithmetic mean, median, mode(s), ...)
 - measure of dispersion (variance, range,)
 - measure of energy (RMS, ...)
 - measure of occurrences (probability, frequencies, ...)
 - functions of these measures (ratio=f1/f2, std/mean, ...)

II. The 5 stages of the data analysis :

1) *data characterizing*



Main characterizing methods

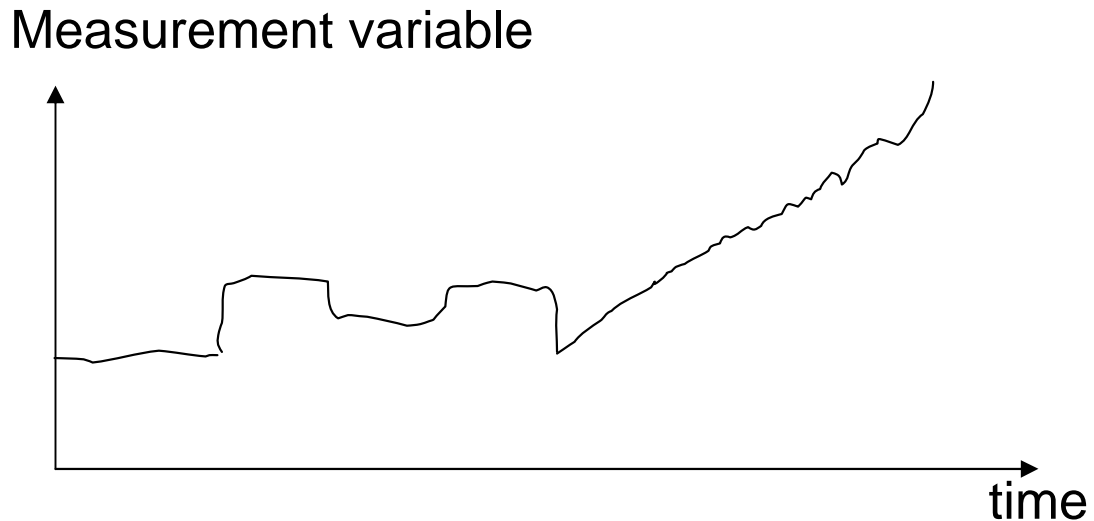
* Methods yielding one or two global (overall) indicators

• **Methods yielding many indicators (from “smoothing”)**

- statistical point of view
- signal processing point of view

II. The 5 stages of the data analysis :

1) *data characterizing*



Main characterizing methods

* Methods yielding one or two global (overall) indicators



* **Methods between these two extreme**

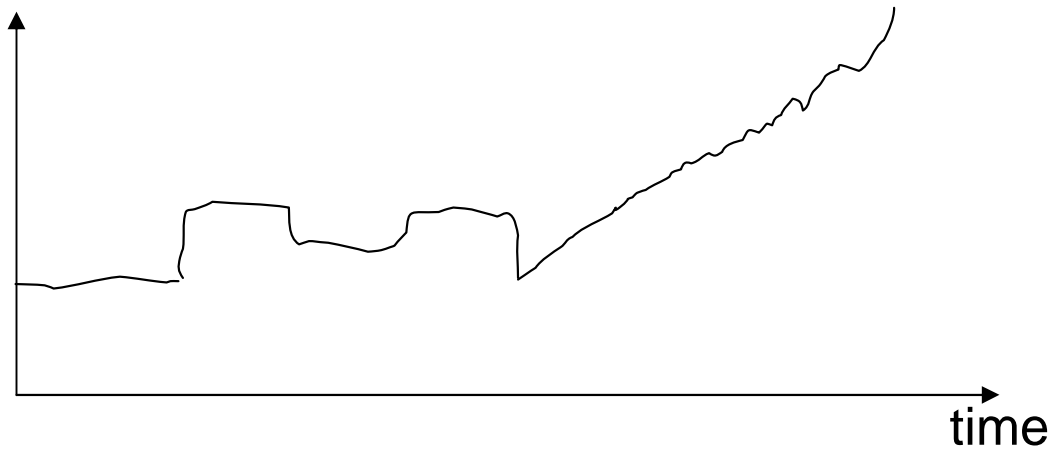


* Methods yielding many indicators (from smoothing)

II. The 5 stages of the data analysis :

1) *data characterizing*

Measurement variable



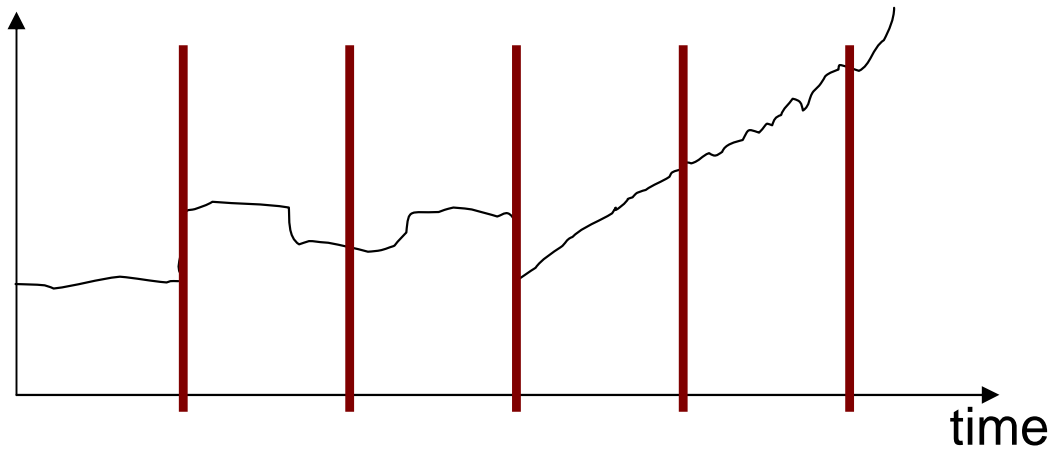
Main characterizing methods

- **Methods between these two extreme :**
Main approach : *the windowing*

II. The 5 stages of the data analysis :

1) *data characterizing*

Measurement variable



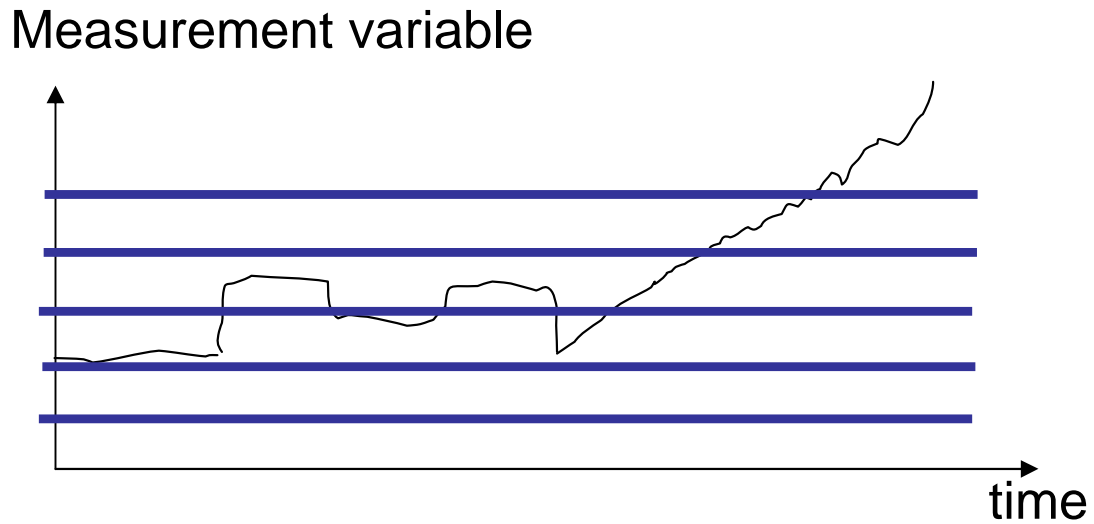
Main characterizing methods

- **Methods between these two extreme :**
Main approach : the windowing

- **time axis**

II. The 5 stages of the data analysis :

1) *data characterizing*



Main characterizing methods

- **Methods between these two extreme :**

Main approach : the windowing

- time axis
- **space axis**
- frequency axis

II. The 5 stages of the data analysis :

1) data characterizing

Main characterizing methods

- **Methods between these two extreme :**

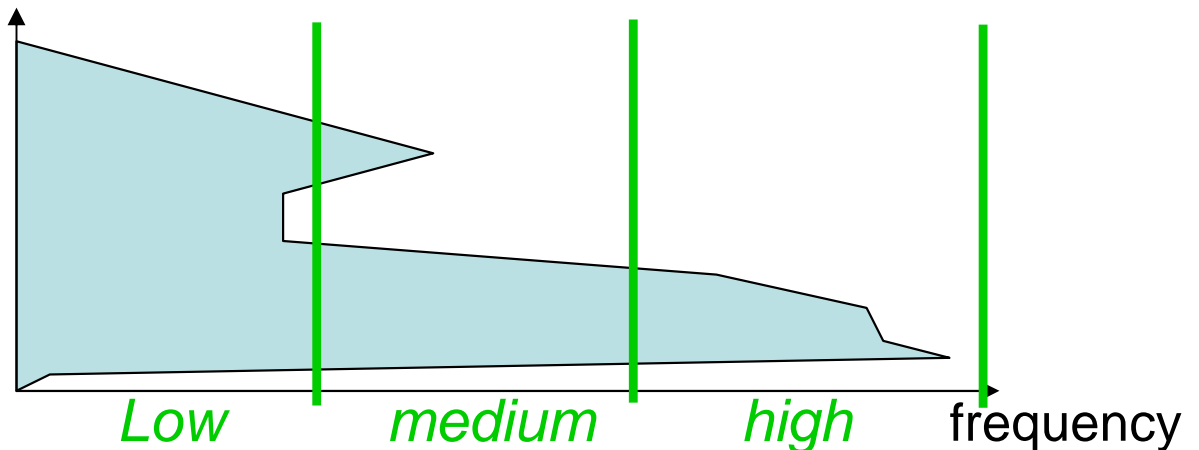
Main approach : the windowing

- time axis
- space axis
- **frequency axis (spectrum and histogram)**

II. The 5 stages of the data analysis :

1) *data characterizing*

Measurement variable



Main characterizing methods

*Magnitude
histogram*

• **Methods between these two extreme :**

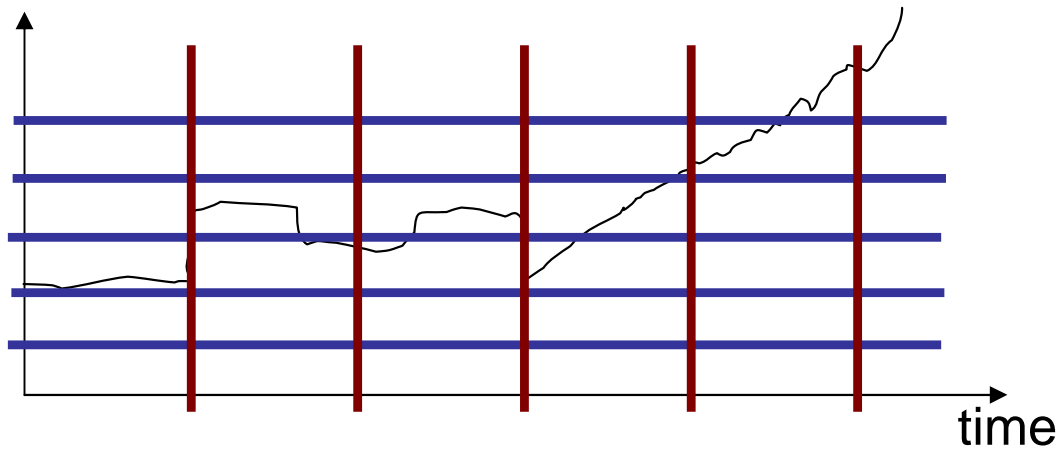
Main approach : the windowing

- time axis
- space axis
- **frequency axis**

II. The 5 stages of the data analysis :

1) *data characterizing*

Measurement variable



Main characterizing methods

*Magnitude
histogram*

• **Methods between these two extreme :**

Main approach : the windowing

- time axis

- space axis

combining

- frequency axis

II. The 5 stages of the data analysis :

2) *data coding*

Main coding methods

• **Methods yielding a scale that keeps the mathematical properties of the initial scale**

e. g. with a quantitative scale

$$\text{var } x \rightarrow \text{var } y = (\text{var } x - a) / b$$

• **Methods yielding a scale that *do not* keep the mathematical properties of the initial scale**

e. g. with a quantitative scale

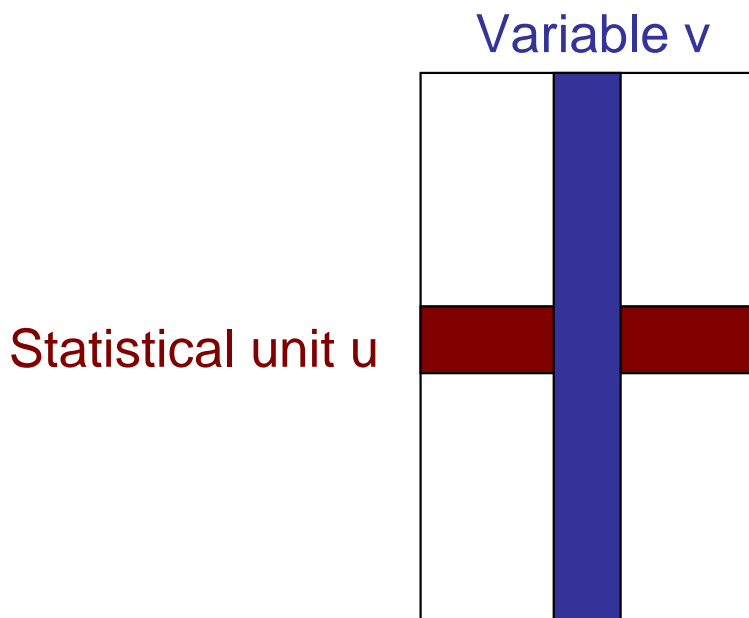
the windowing

II. The 5 stages of the data analysis :

3) *data shaping*

Main data shaping methods

- **Methods yielding one two-entries table**

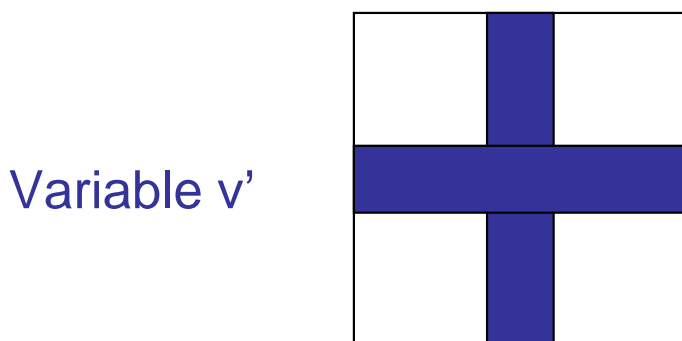
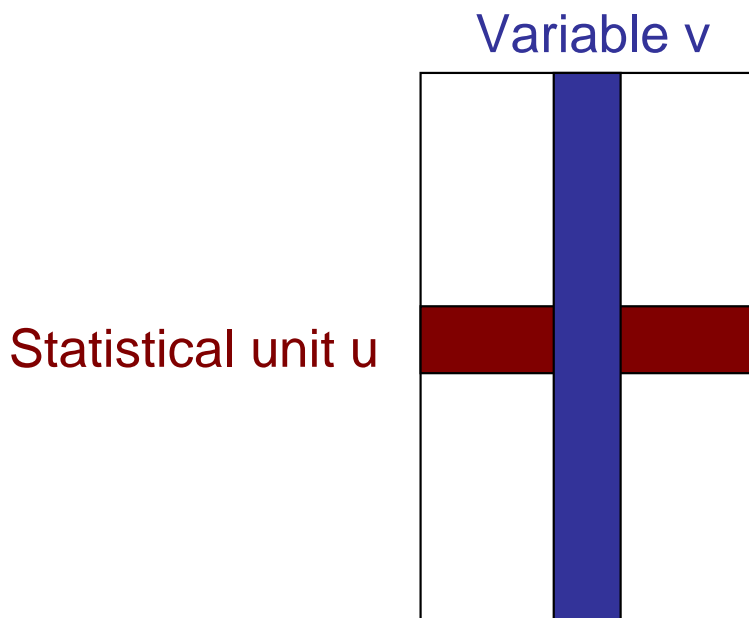


II. The 5 stages of the data analysis :

3) *data shaping*

Main data shaping methods

- **Methods yielding one two-entries table**

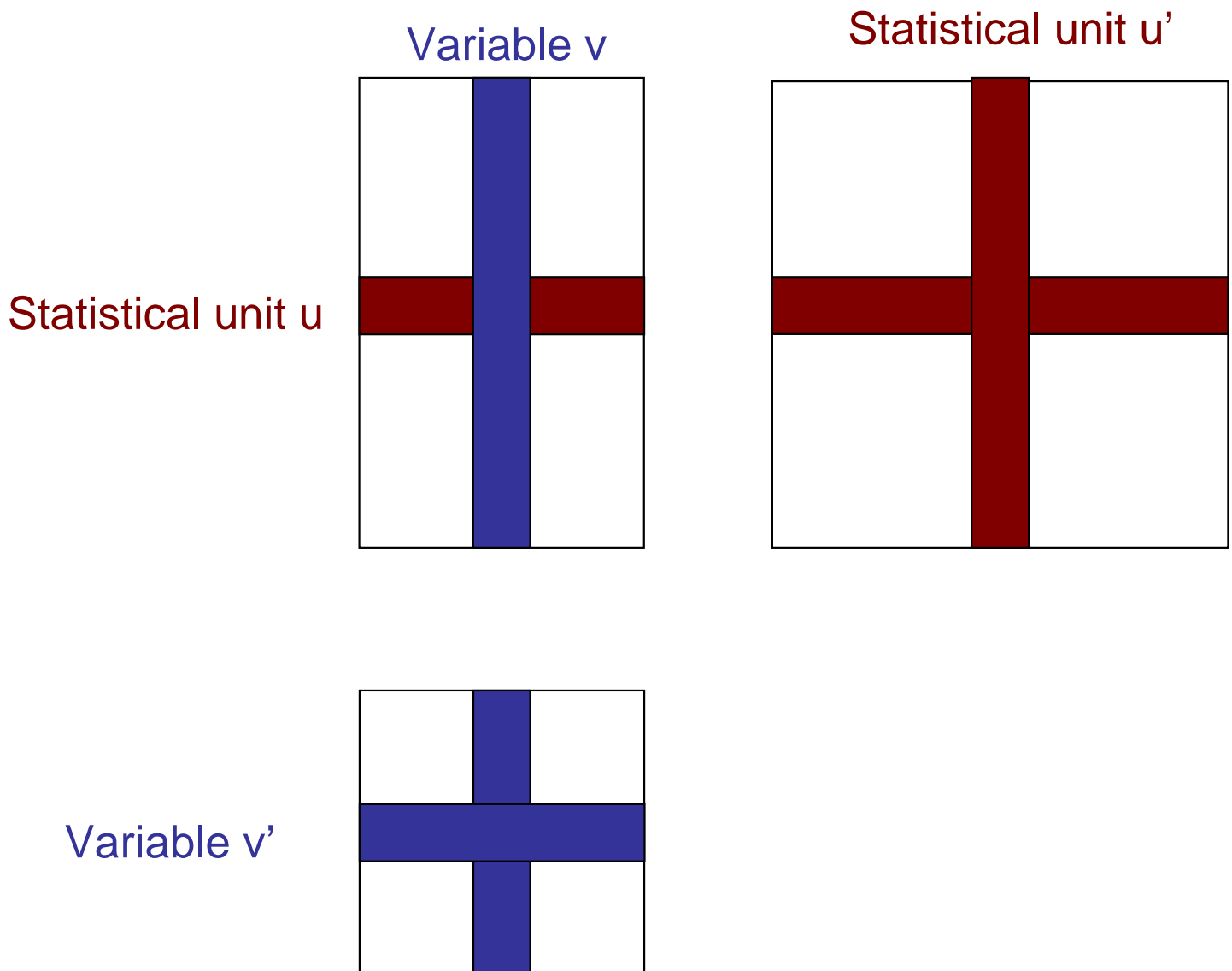


II. The 5 stages of the data analysis :

3) *data shaping*

Main data shaping methods

* **Methods yielding one two-entries table**



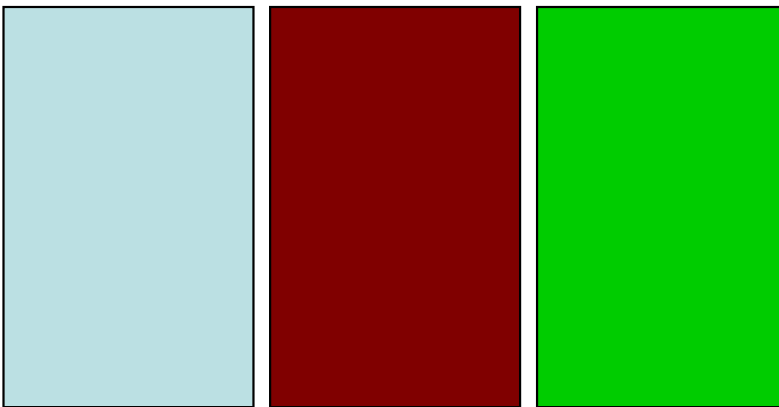
II. The 5 stages of the data analysis :

3) *data shaping*

Main data shaping methods

•Methods yielding one two-entries table

***Methods yielding several two-entries tables**



II. The 5 stages of the data analysis :

3) *data shaping*

Main data shaping methods

•Methods yielding one two-entries table

***Methods yielding several two-entries tables**



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II. The 5 stages of the data analysis :

3) data shaping

Main data shaping methods

•Methods yielding one two-entries table

***Methods yielding several two-entries tables**

* ...

II. The 5 stages of the data analysis :

4) Relation and/or class obtaining

Main methods => 3 taxonomic dimensions

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4) Relation and/or class obtaining

Main methods => 3 taxonomic dimensions

* Descriptive	vs.	inference
mean		t test
histogram		F test
scatterplot		Chi-2 test
...	...	

II. The 5 stages of the data analysis :

4) *Relation and/or class obtaining*

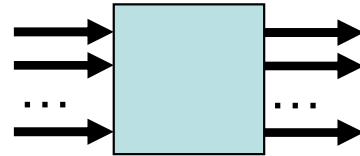
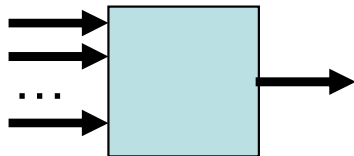
Main methods => 3 taxonomic dimensions

* Descriptive	vs.	inference
mean		t test
histogram		F test
scatterplot		Chi-2 test

...

...

* Monovariate	vs.	multivariate
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II. The 5 stages of the data analysis :

4) *Relation and/or class obtaining*

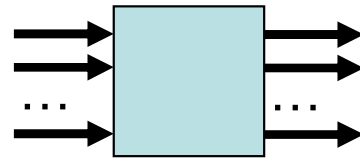
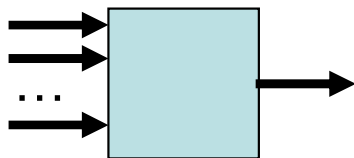
Main methods => 3 taxonomic dimensions

* **Descriptive** vs. **inference**
mean t test
histogram F test
scatterplot Chi-2 test

...

...

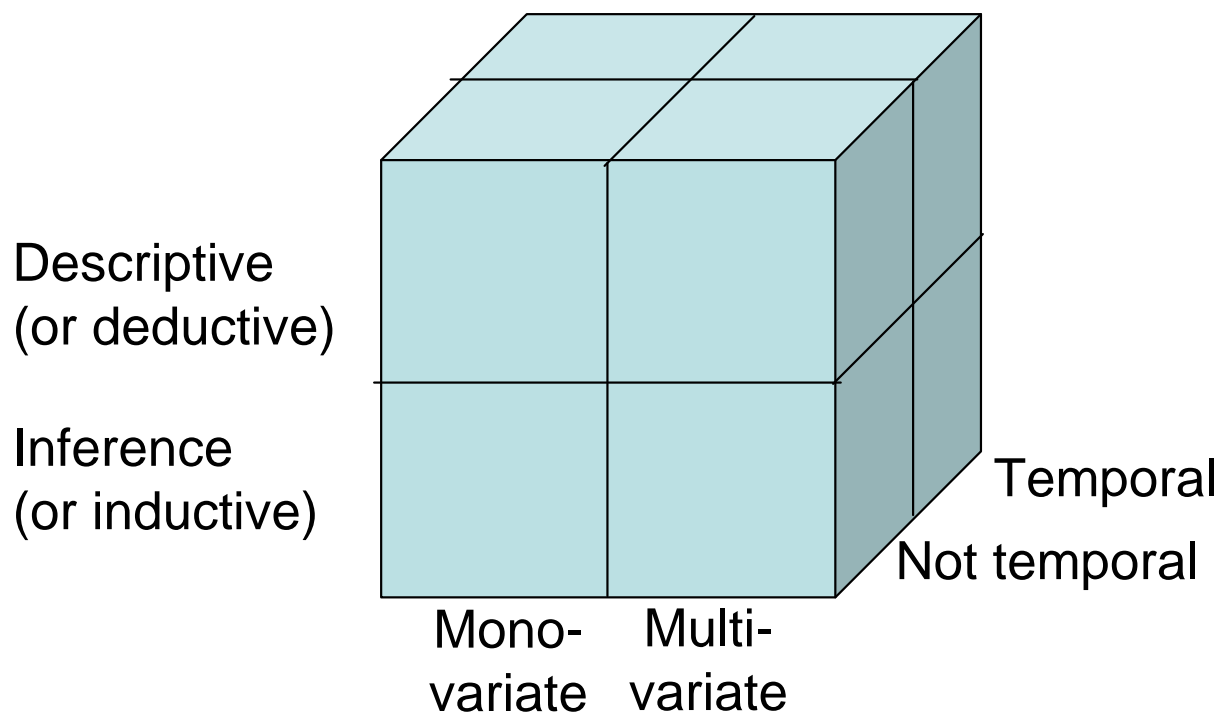
* **Monovariate** vs. **multivariate**



* **Non temporal** vs. **temporal**
the time is introduced in the model

II. The 5 stages of the data analysis :

4) *Relation and/or class obtaining*



II. The 5 stages of the data analysis :

5) Final result presentation

Main methods

* graphical

histogram

spectrum

dendrogram

factor plane...

II. The 5 stages of the data analysis :

5) Final result presentation

Main methods

* graphical

histogram

spectrum

dendrogram

factor plane...

* verbal

the output of a test method

“ the factor f has an influence on the variable v , $F=...$ $p=...$ ”

II. The 5 stages of the data analysis :

5) *Final result presentation*

Main methods

* graphical

histogram

spectrum

dendrogram

factor plane...

* verbal

the output of a test method

“ the factor f has an influence on the variable v , $F=...$ $p=...$ ”

* mathematical

$$v = 3.5 f - 0.2 f^2 + \dots$$

II. The 5 stages of the data analysis :

The existence of many analysis paths



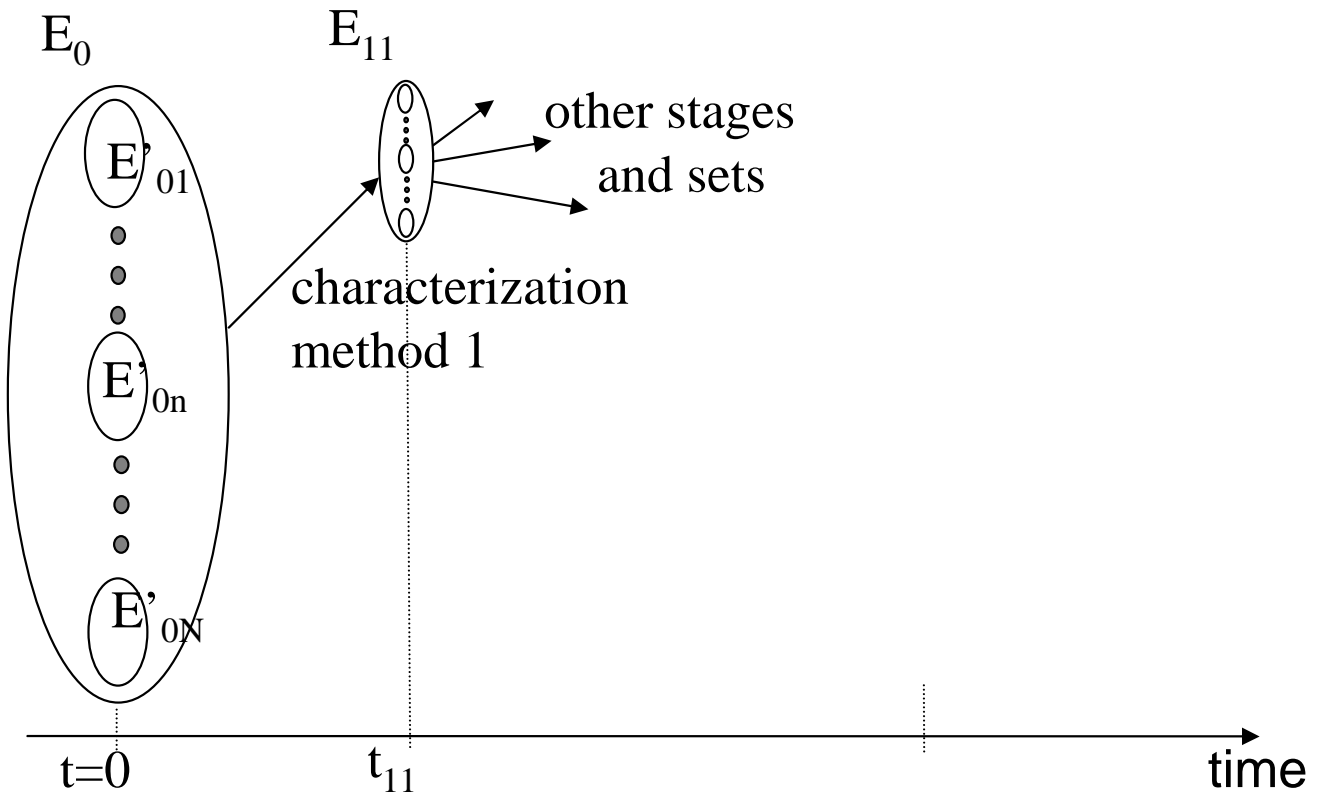
notation :

$n=1, \dots, N$

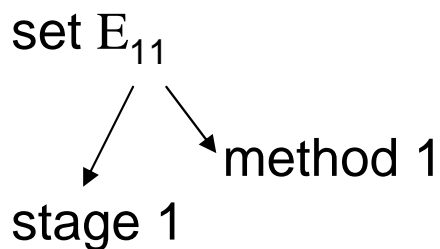
index 0 = initial data set

II. The 5 stages of the data analysis :

The existence of many analysis paths

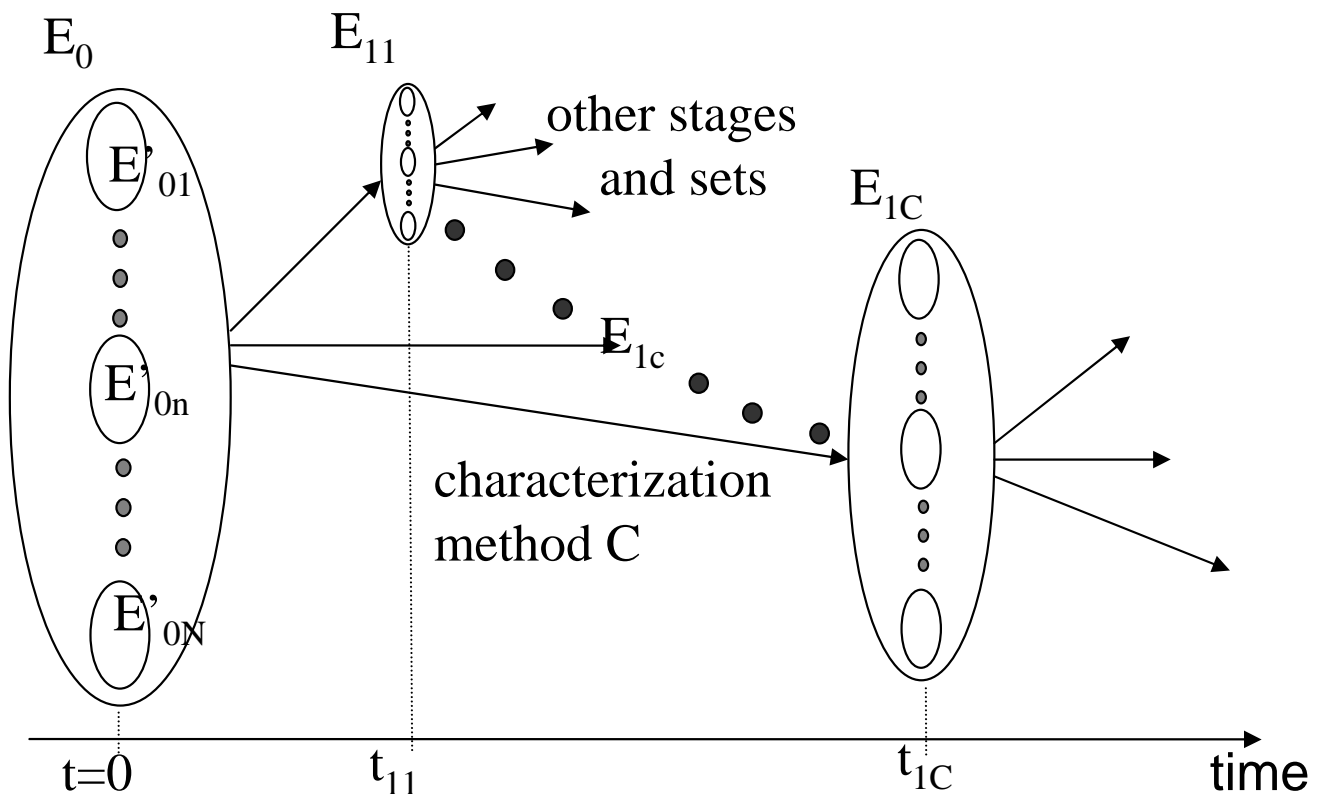


notation :



II. The 5 stages of the data analysis :

The existence of many analysis paths



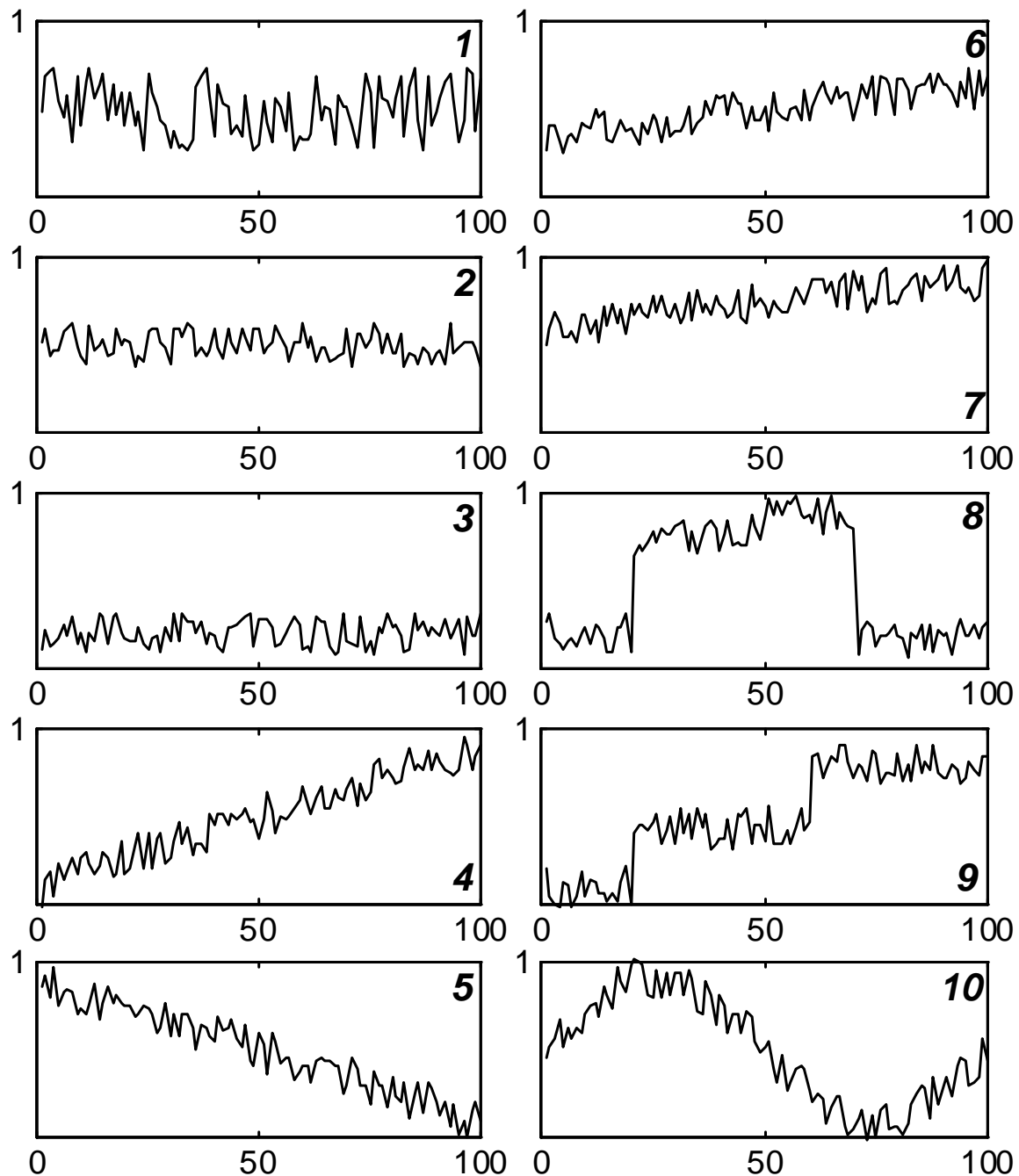
legend : the size of an oval indicate the size of the set

the position along the horizontal axis
indicates the time spent to get this set

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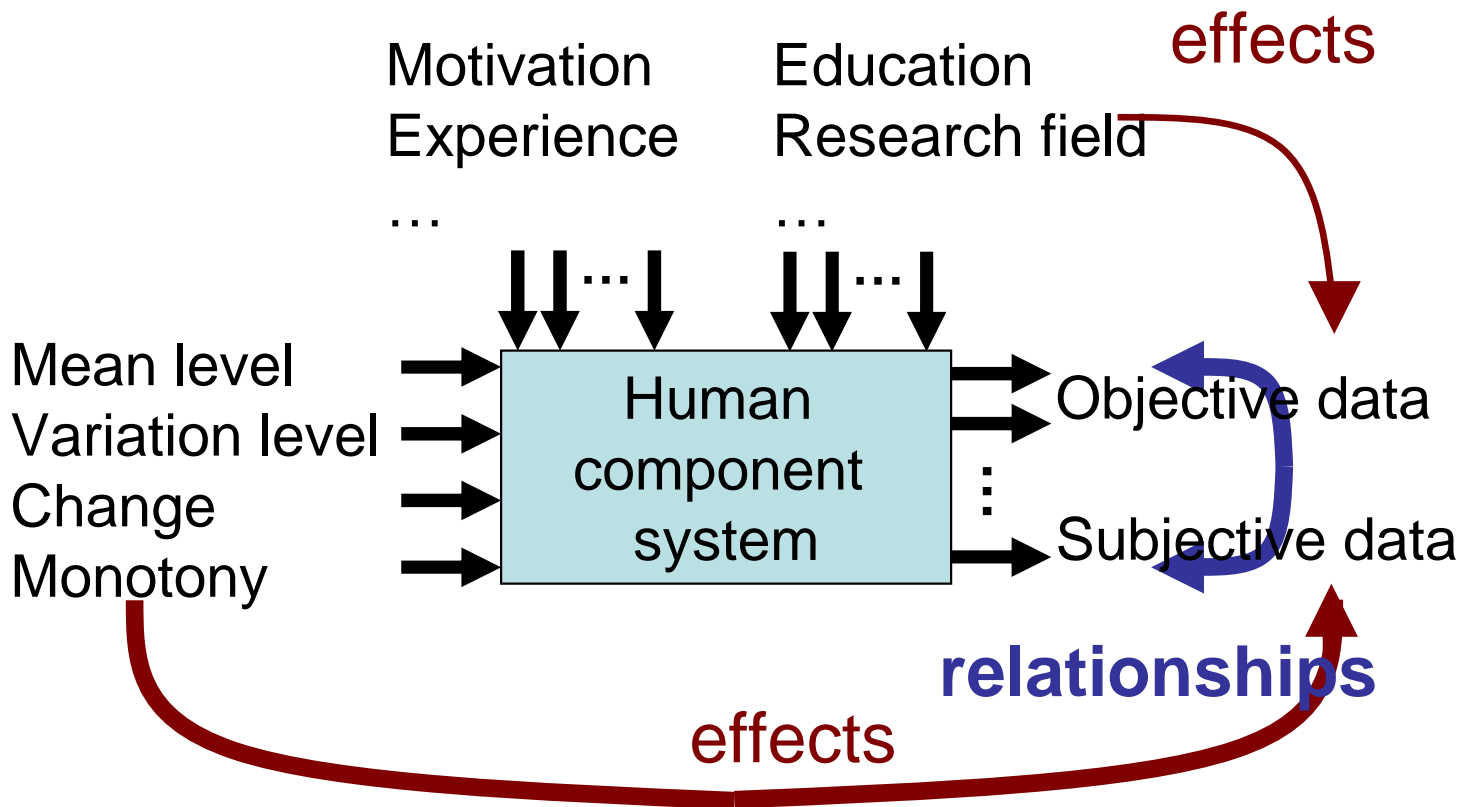
III. The first stage: Data characterization

*An experiment with 10 signals
(10 data sets with 100 values)*



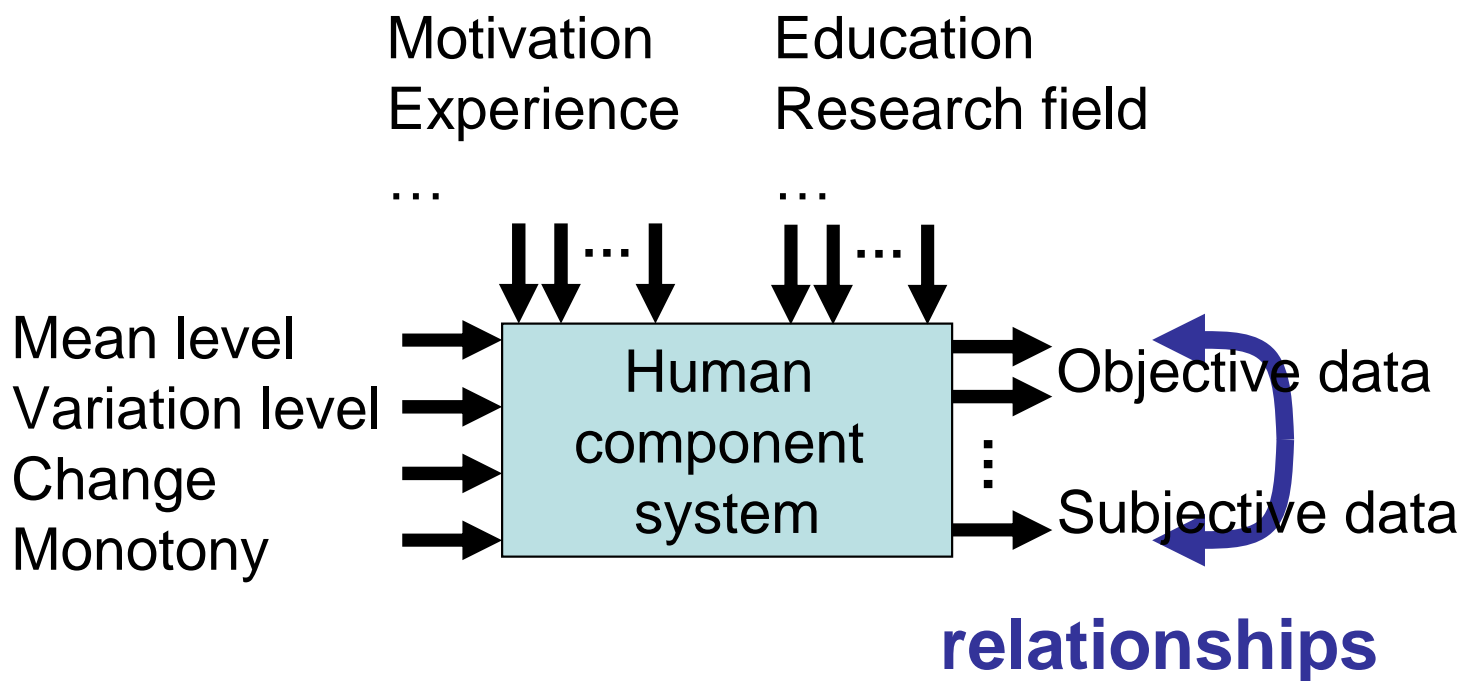
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*An experiment with 10 signals
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III. The first stage: Data characterization

*An experiment with 10 signals
(10 data sets with 100 values)*



III. The first stage: Data characterization

*An experiment with 10 signals
and a comparative analysis of characterization methods*

“Classic” methods

1) Arithmetic mean

2) RMS value

III. The first stage: Data characterization

*An experiment with 10 signals
and 4 characterization methods*

Classic methods

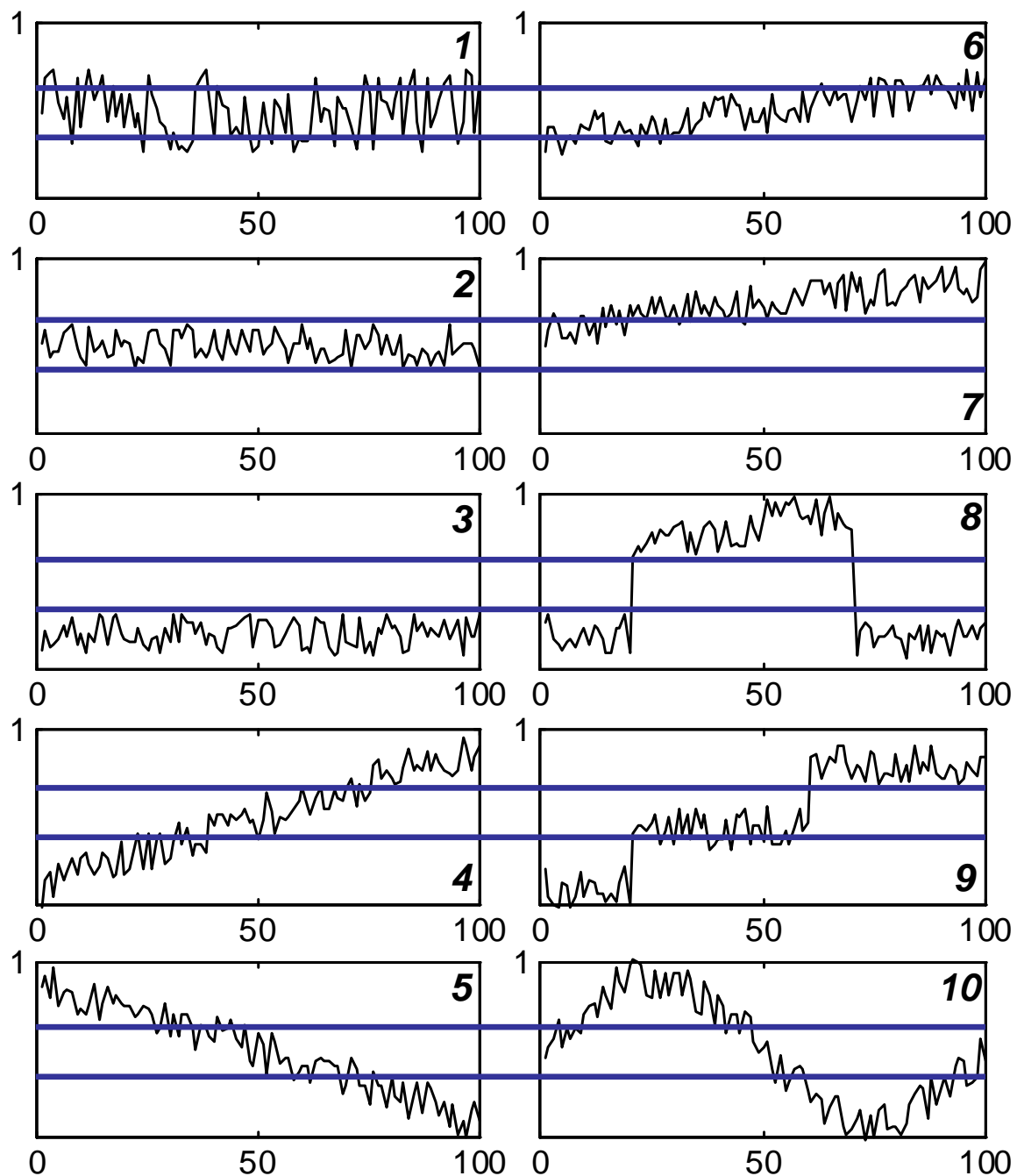
1) Arithmetic mean

2) RMS value

Windowing-based methods

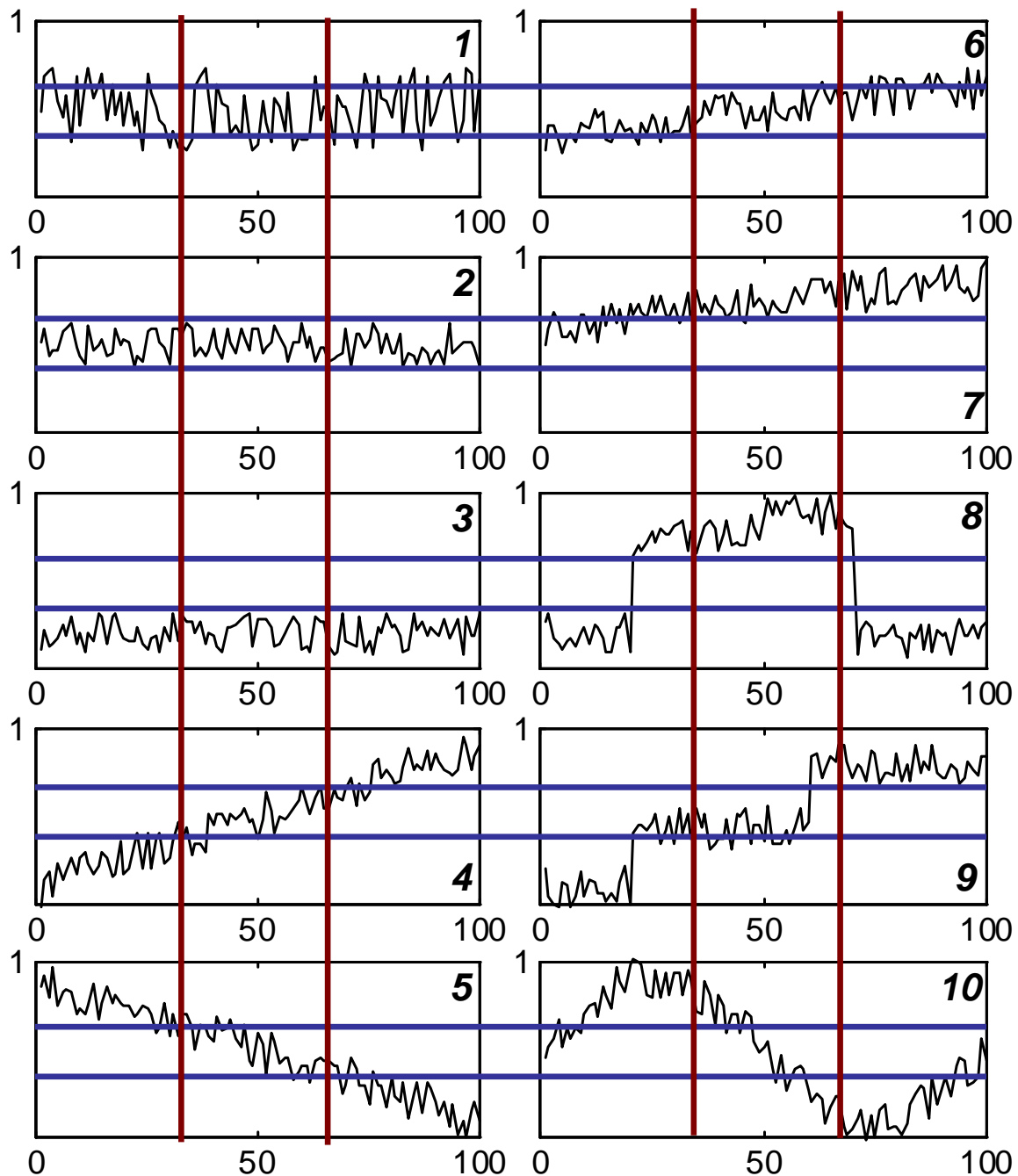
III. The first stage: Data characterization

*An experiment with 10 signals
and **Space** windowing*



III. The first stage: Data characterization

*An experiment with 10 signals
and **Space-time** windowing*



III. The first stage: Data characterization

*An experiment with 10 signals
and 4 characterization methods*

Classic methods

1) Arithmetic mean

2) RMS value

Windowing-based methods

3) **space** windowing → **3** Membership Value Averages (MVA)

4) **space-time** windowing → **3*3** = 9 MVA

III. The first stage: Data characterization

*An experiment with 10 signals
and 4 characterization methods*

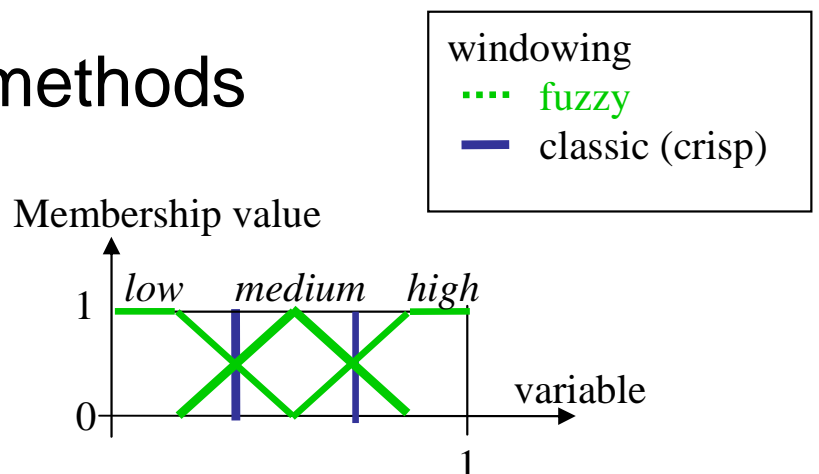
Classic methods

1) Arithmetic mean

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Windowing-based methods

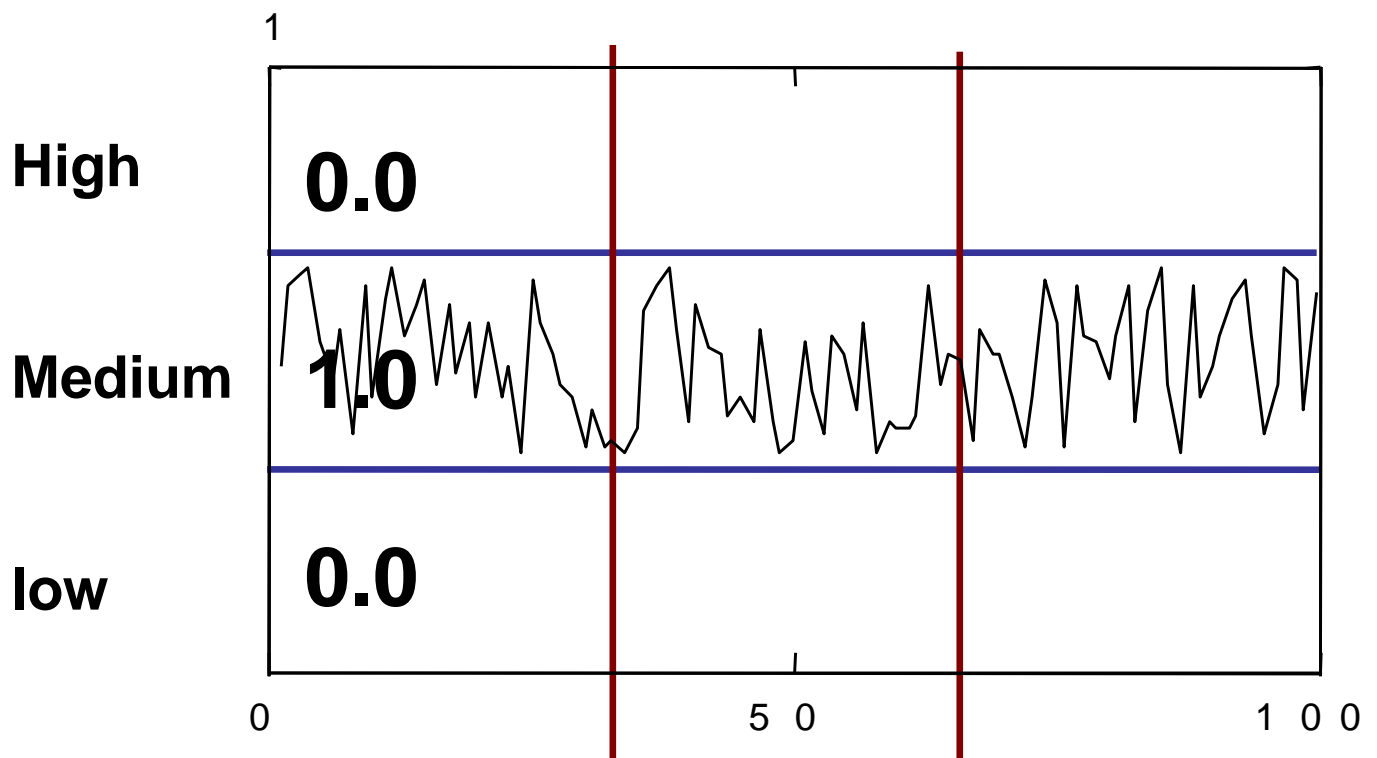
3) 3 Membership Value
Average (MVA)



4) $3 \times 3 = 9$ MVA

III. The first stage: Data characterization

*An experiment with 10 signals
and **Space-time** windowing*



3

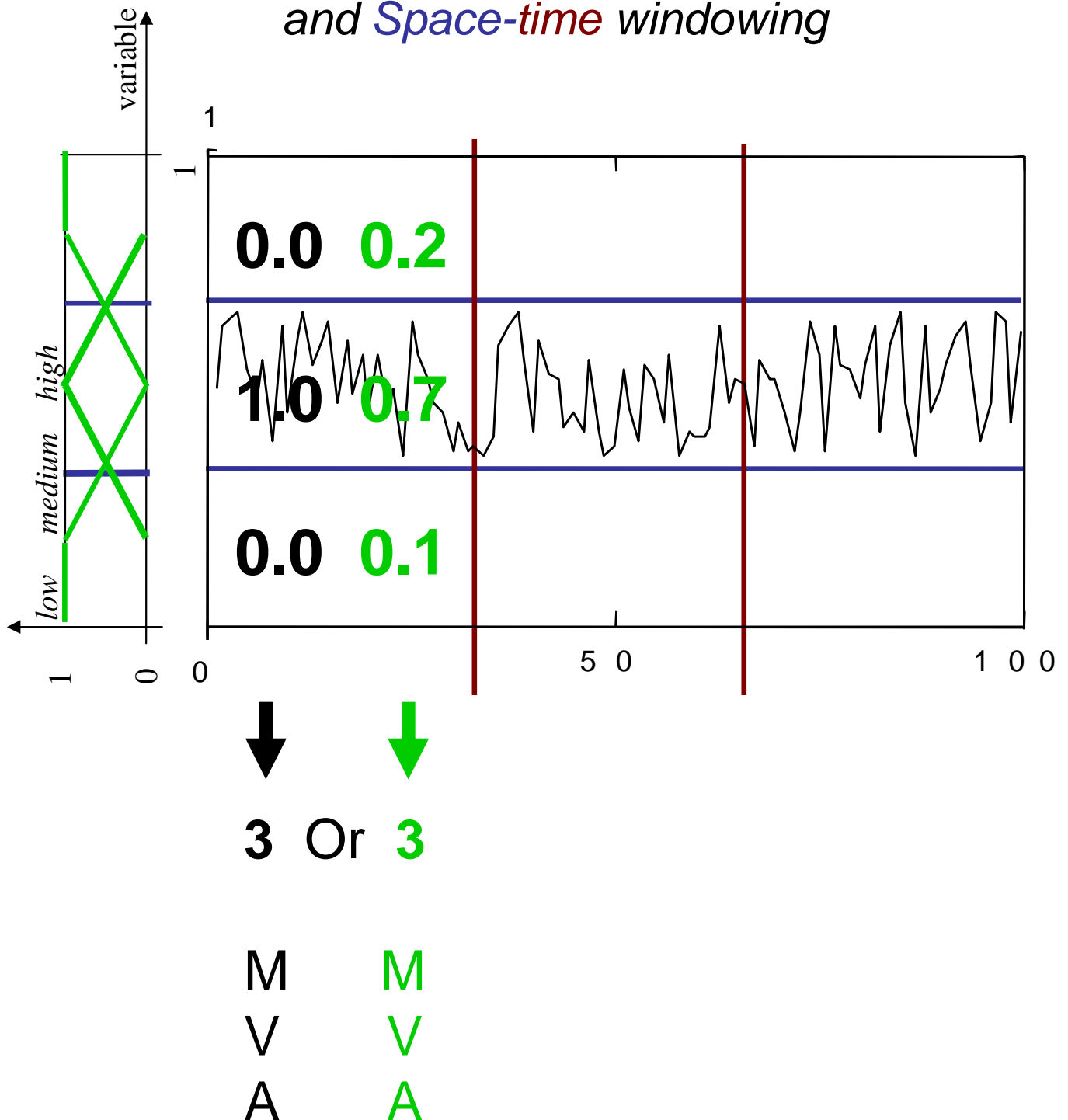
M

V

A

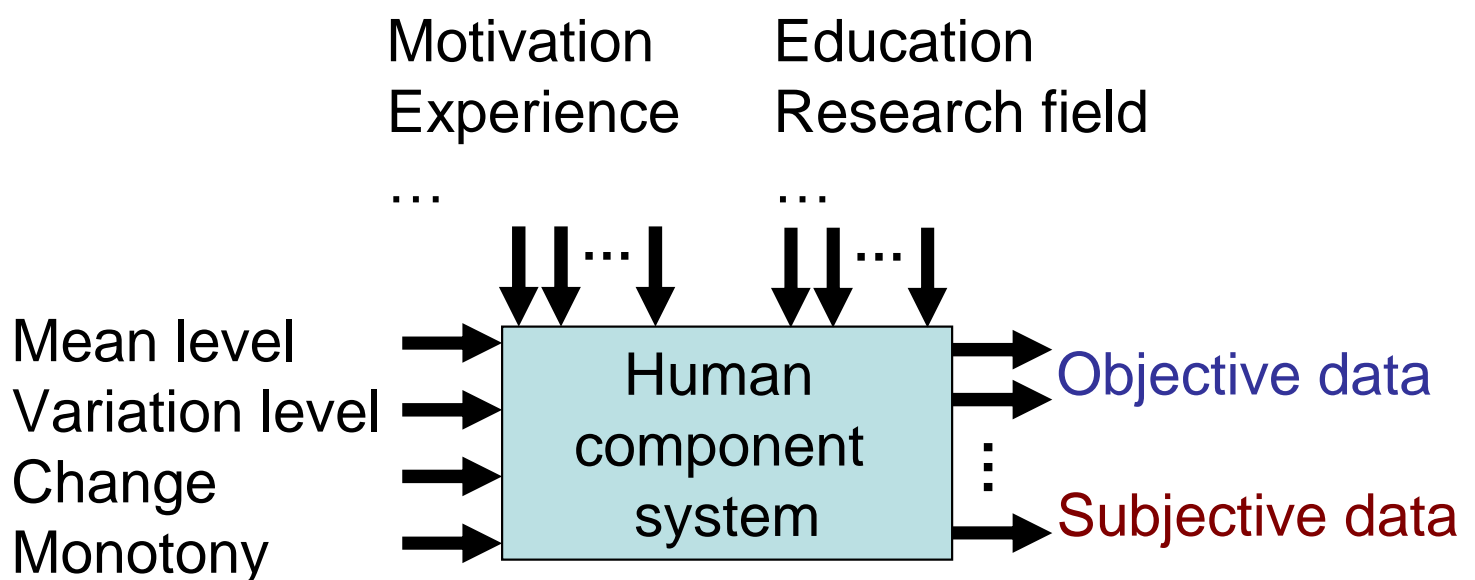
III. The first stage: Data characterization

An experiment with 10 signals
and *Space-time* windowing



III. The first stage: Data characterization

*An experiment with 10 signals
(10 data sets with 100 values)*

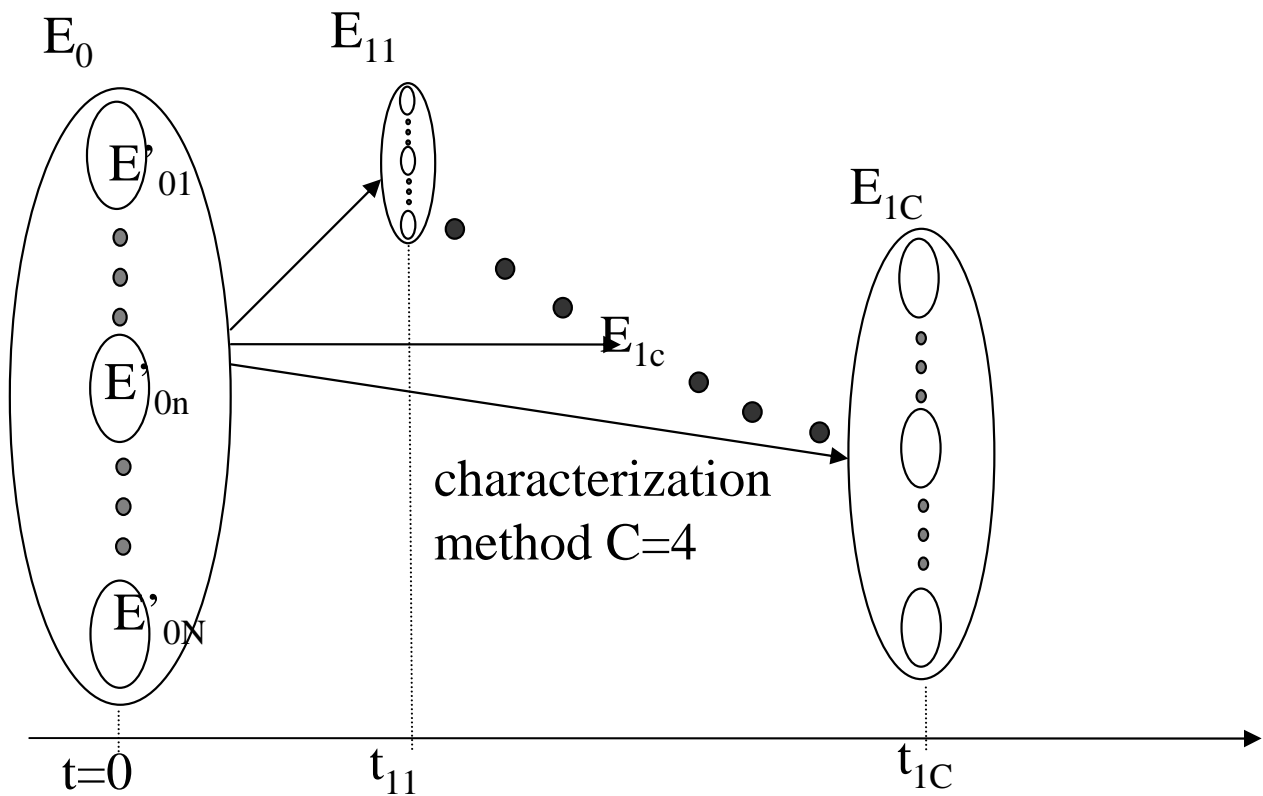


“Objective” evaluation (from quantitative data with the 4 characterization methods)

“Subjective” evaluation (from subjective data with experts)

III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“**OBJECTIVE**” evaluation

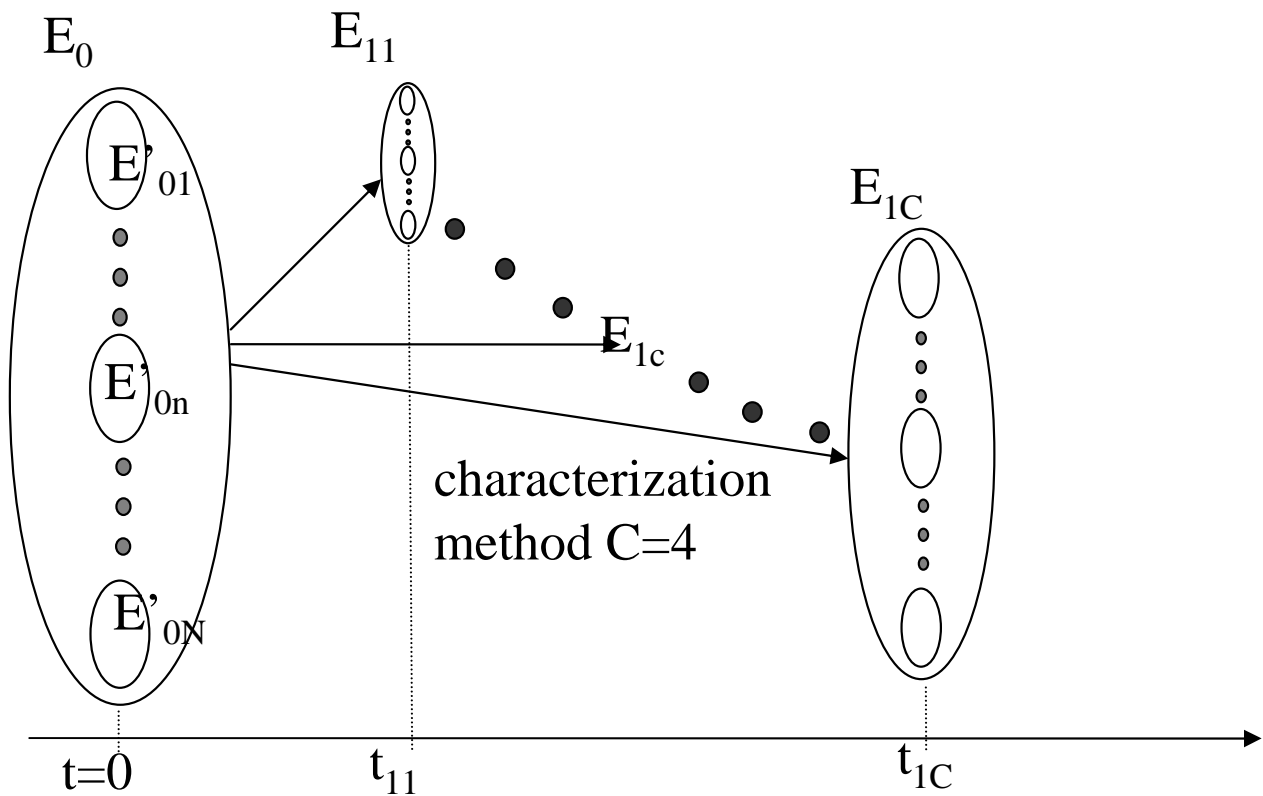


Many criteria

1) based on the notion of data reduction

III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“**OBJECTIVE**” evaluation

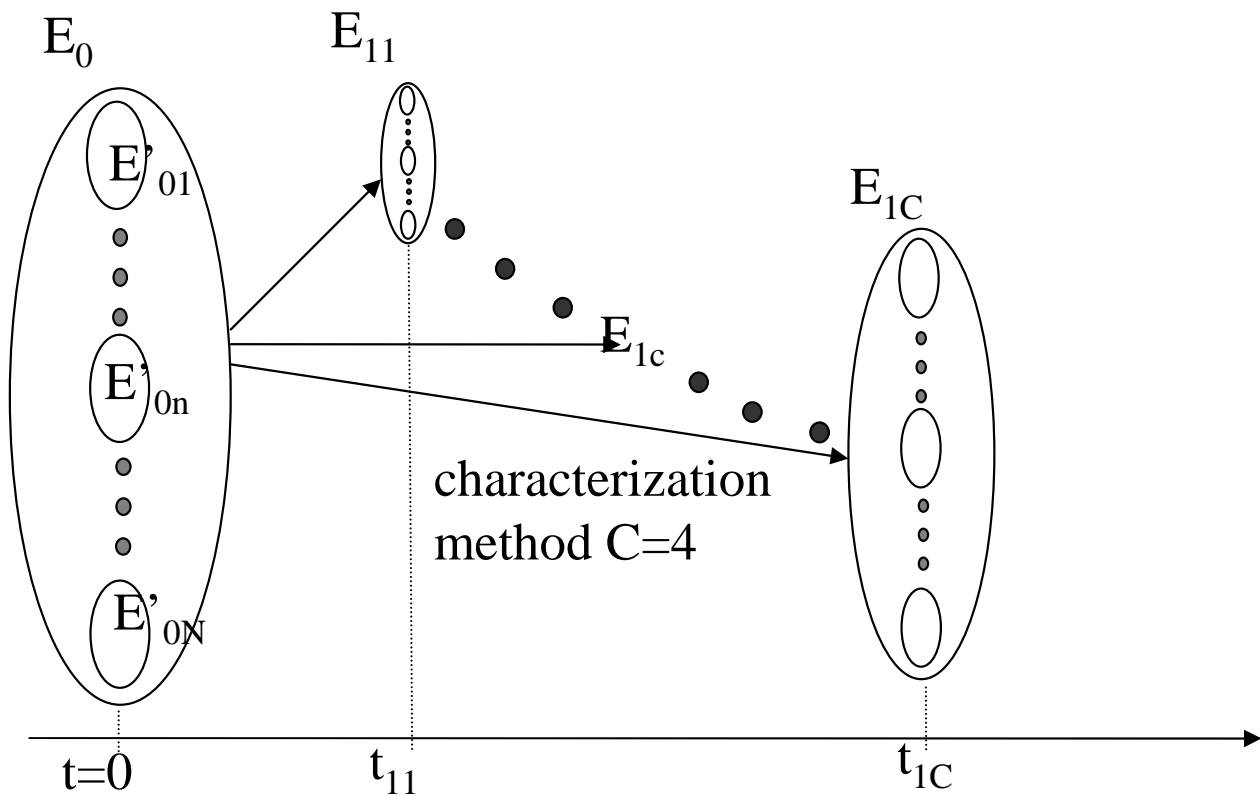


Many criteria

- 1) based on the notion of data reduction
- 2) analysis duration

III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“**OBJECTIVE**” evaluation

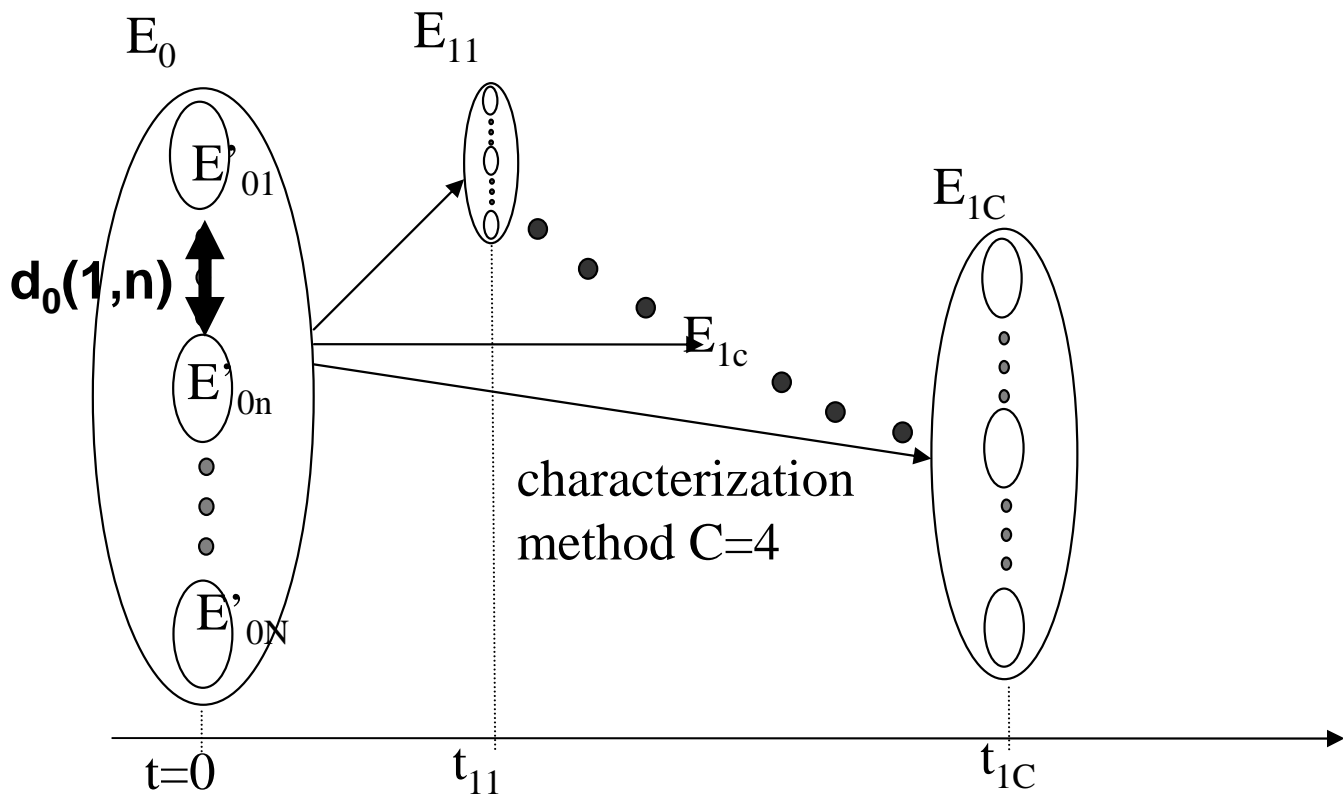


Many criteria

- 1) based on the notion of data reduction
- 2) analysis duration
- 3) distance

III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“OBJECTIVE” evaluation



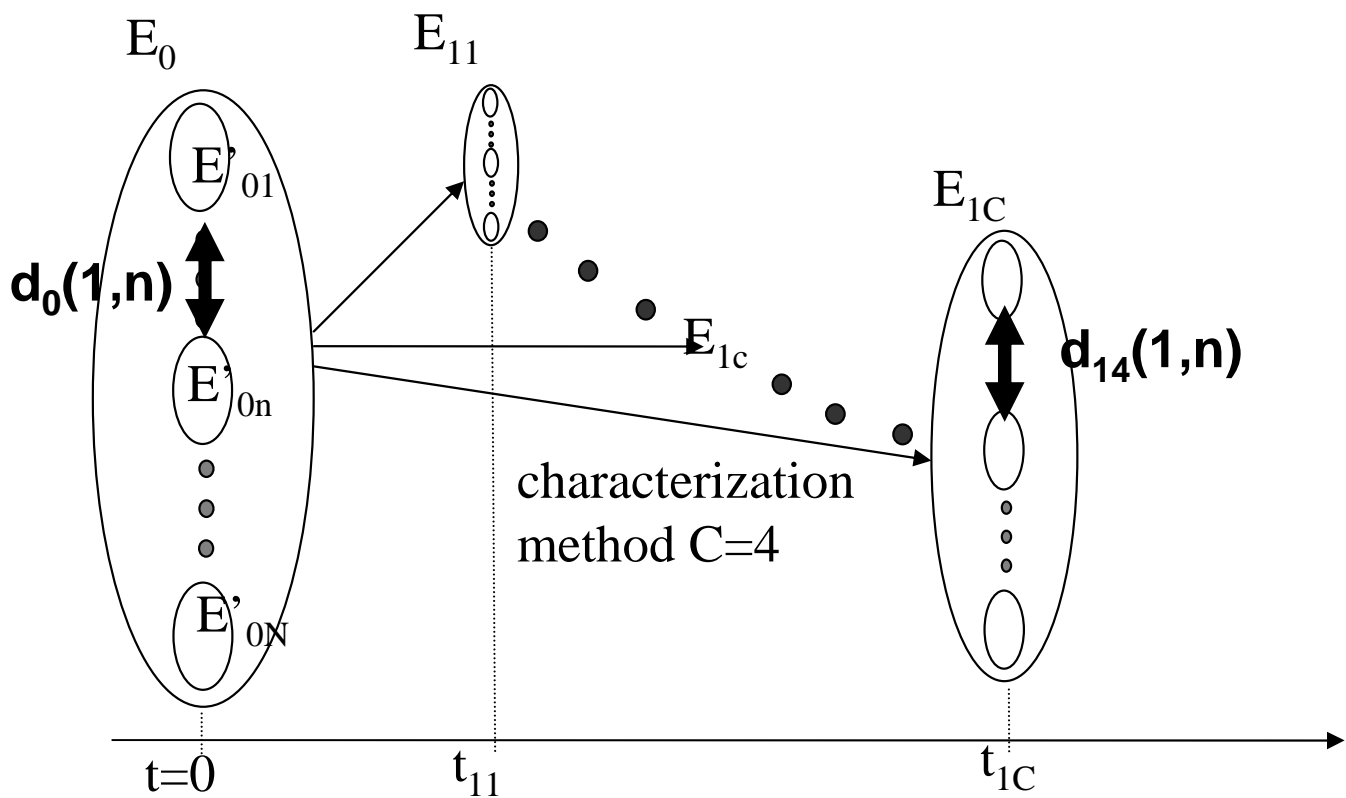
Many criteria

- 1) based on the notion of data reduction
- 2) analysis duration
- 3) distance indicator

$$d_0(1, n) = \sum_{k=1}^{100} |x_{1k} - x_{nk}|$$

III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“OBJECTIVE” evaluation



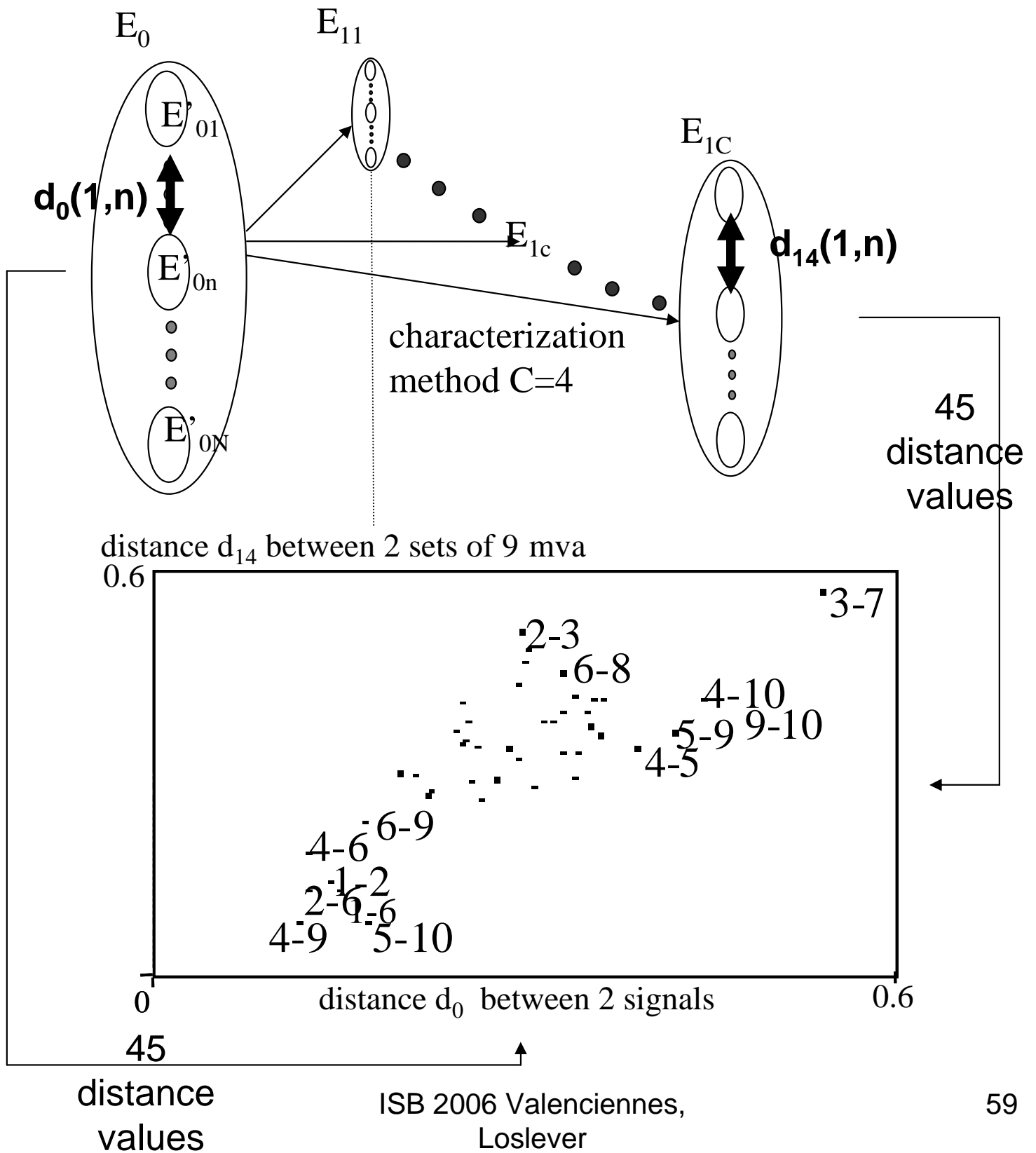
Many criteria

- 1) based on the notion of data reduction
- 2) analysis duration
- 3) distance indicator

$$d_{14}(1, n) = \frac{1}{9} \sum_{w=1}^9 |mva_{1w} - mva_{nw}|$$

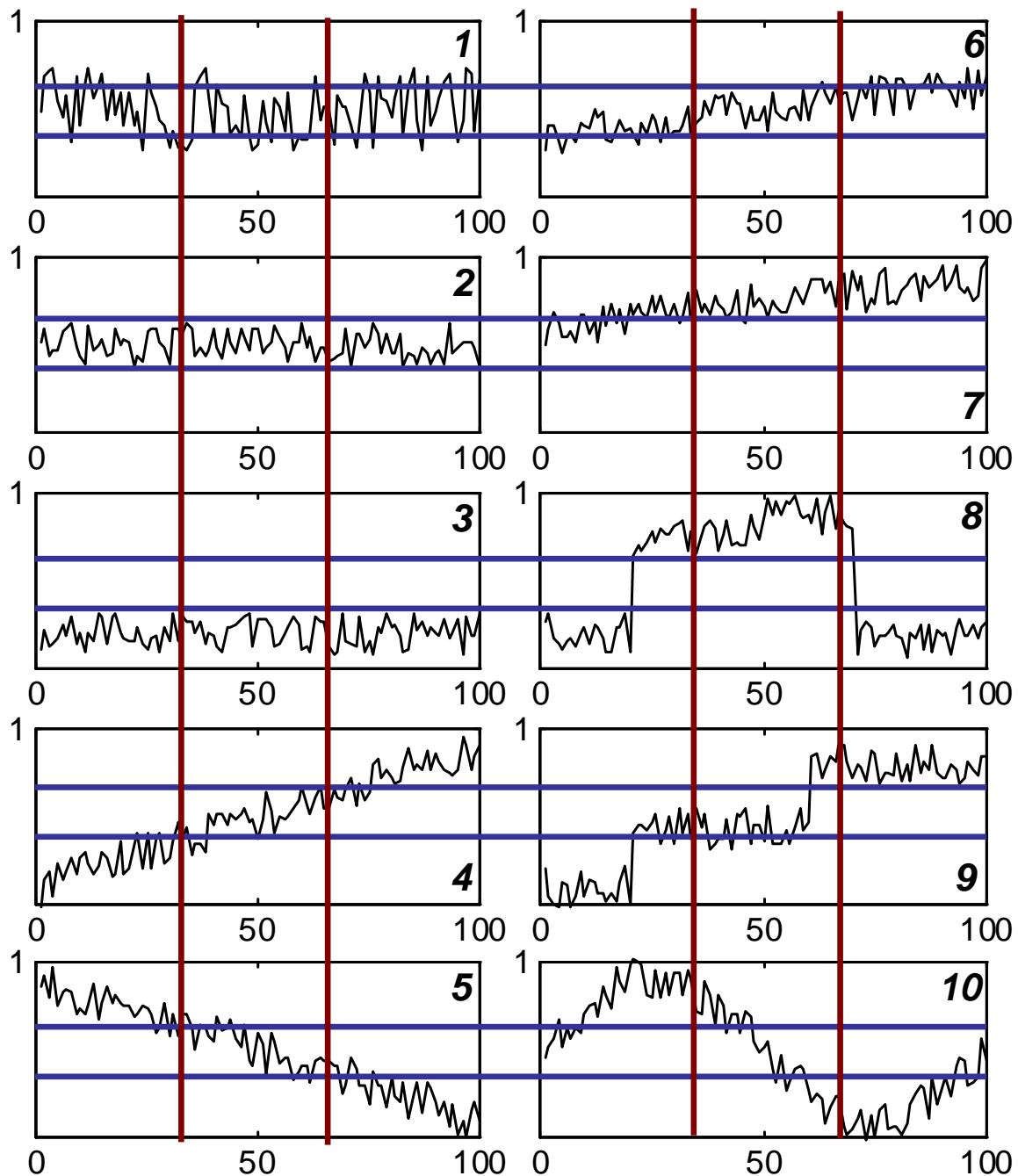
III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“OBJECTIVE” evaluation



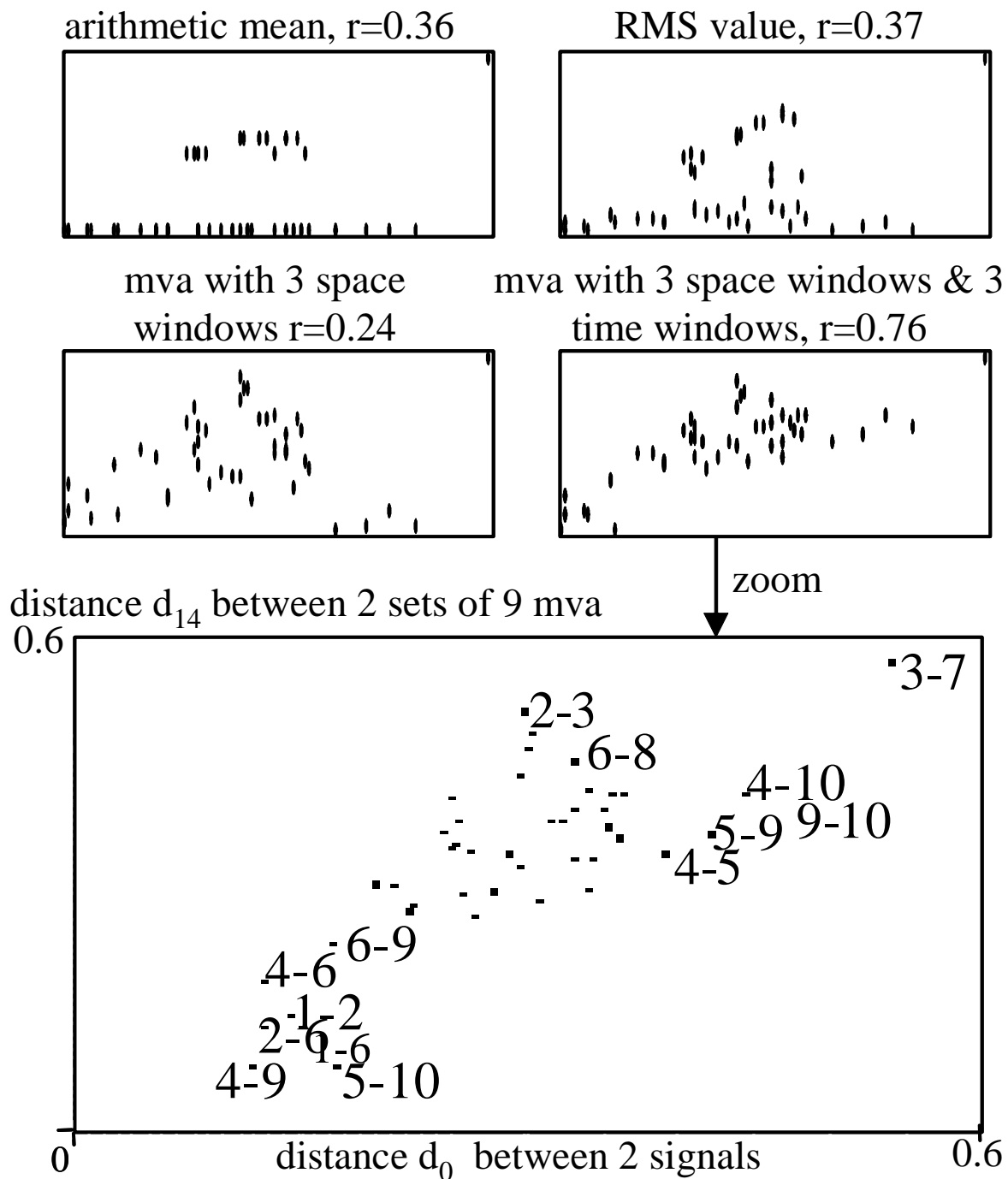
III. The first stage: Data characterization

*An experiment with 10 signals
and **Space-time** windowing*



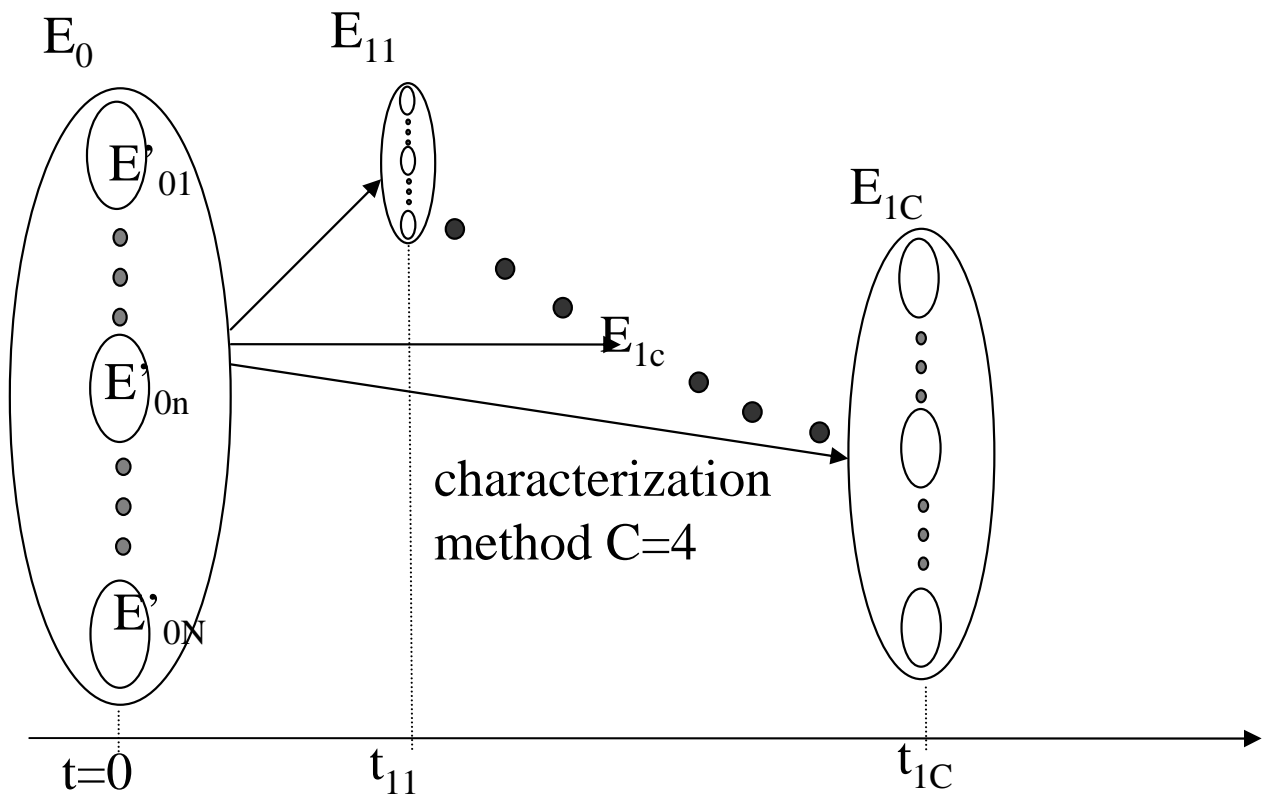
III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“OBJECTIVE” evaluation



III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“**OBJECTIVE**” evaluation



Many criteria

- 1) based on the notion of data reduction
- 2) analysis duration
- 3) distance indicator & correlation indicator r

III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“SUBJECTIVE” evaluation with 30 individuals

“These 10 signals were recorded for 10 individuals under identical conditions (i.e., same task and environment)”. Please answer the 4 questions:

Q1. Among the 10 signals, indicate the two signals A and B that **most resemble one another**:

A (from 1 to 10) : [], B (from 1 to 10) : []

Q2. Apart from these 2 signals, indicate the two signals C and D that most resemble one another:

C (from 1 to 10) : [], D (from 1 to 10) : []

Q3. Among the 10 signals, indicate the two signals E and F that **least resemble one another**:

E (from 1 to 10) : [], F (from 1 to 10) : []

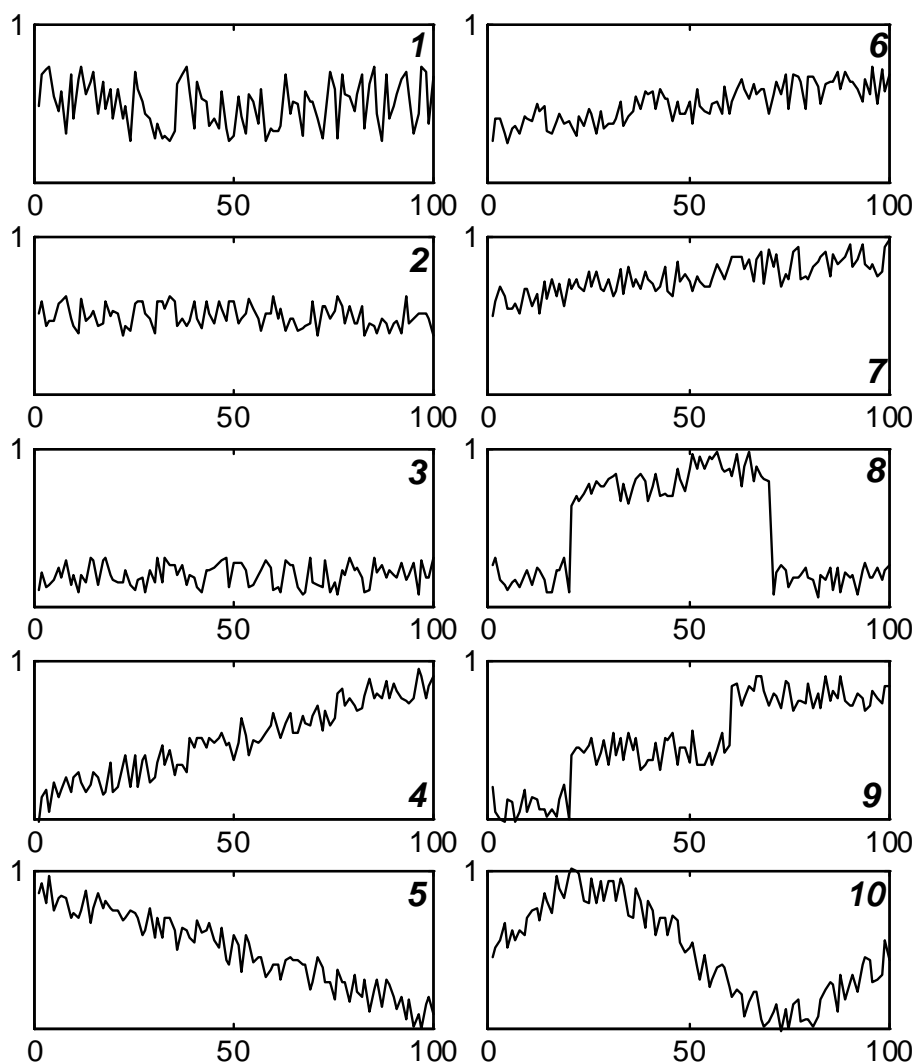
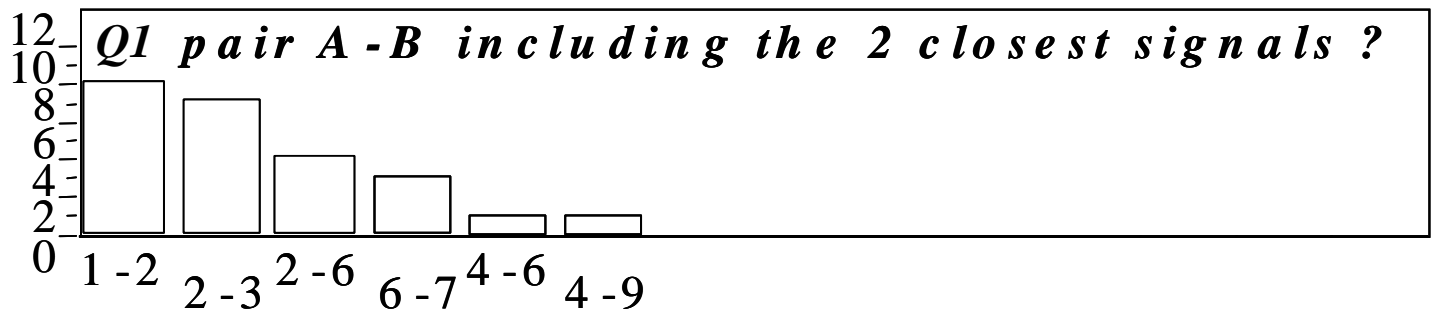
Q4. Apart from these 2 signals, indicate the two signals G and H that least resemble one another:

G (from 1 to 10) : [], H (from 1 to 10) : []

III. The first stage: Data characterization

An experiment with $N=10$ signals and $C=4$ methods
“SUBJECTIVE” evaluation

frequency of responses



III. The first stage: Data characterization

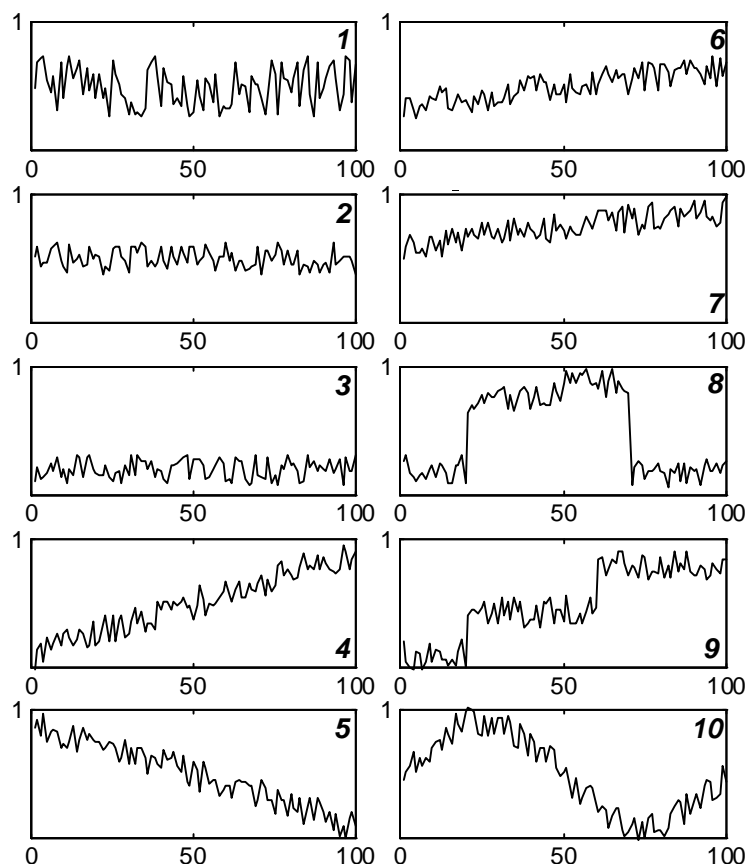
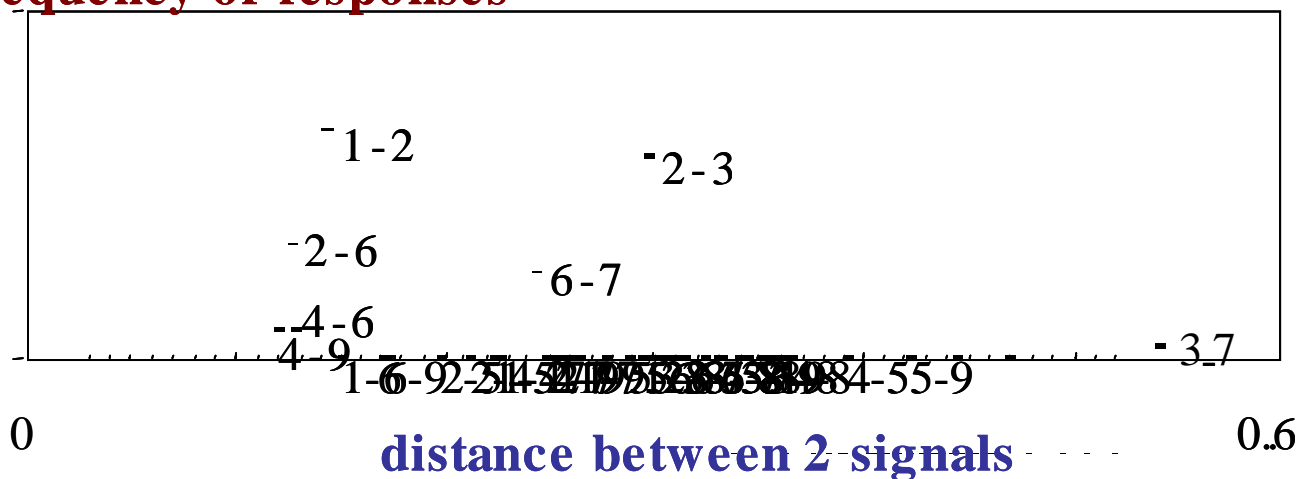
An experiment with $N=10$ signals and $C=4$ methods

Connection between

“**OBJECTIVE**” and “**SUBJECTIVE**”

Evaluations (30 experts)

frequency of responses



III. The first stage: Data characterization

Some comments about the experiment and the results

For the choice of a characterization method, two principle cases can be envisaged and tested:

*** Choosing a characterization method where expert opinions about the signal resemblance and/or dissemblance are recorded**

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*** Choosing a characterization method where expert opinions about the signal resemblance and/or dissemblance are recorded**

=> An experimental design is required

*** Choosing a characterization method without taking into account opinions about the signal resemblance and/or dissemblance**

=> An experimental design is not required

III. The first stage: Data characterization

Some comments about the experiment and the results

*** Choosing a characterization method without taking into account opinions about the signal resemblance and/or dissemblance**

2 major types of discourse are possible :

III. The first stage: Data characterization

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a) *“the time data are characterized using the method CH1.”*

b) *“the data can be characterized using methods CH1, CH2, ..., CHC; the criteria for the choice are CR1, CR2, ..., CRR; given these ones, the selected method is CHs.”*

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III. The first stage: Data characterization

Some comments about the experiment and the results

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often used & no (low) subjectivity

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III. The first stage: Data characterization

Some comments about the experiment and the results

c) *“Given all the existing methods, all the methods I have heard about and all the methods I really know, I select method CHs”.*

III. The first stage: Data characterization

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Such discourse acknowledges the part of **subjectivity** that exists when choices are made

III. The first stage: Data characterization

Some comments about the experiment and the results

c) *“Given all the existing methods, all the methods I have heard about and all the methods I really know, I select method CHs”.*

Such discourse acknowledges the part of **subjectivity** that exists when choices are made

My own experience

CHs based on

space- windowing

III. The first stage: Data characterization

Some comments about the experiment and the results

c) *“Given all the existing methods, all the methods I have heard about and all the methods I really know, I select a method based on space- windowing. The number of space windows is ... and the MVA are investigated through ...»*

III. The first stage: Data characterization

Why space-windowing ?

3D measurement devices =>

Many good points

+

+

+

+

+

+

Few bad points

-

-

III. The first stage: Data characterization

Why space-windowing ?

With 3D measurement devices
it is more and more easy to record
+ many variables at the same time
(more than 50 variables)
+ with large sampling frequencies
(more than 50 Hz)
+ with long durations

III. The first stage: Data characterization

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With 3D measurement devices
it is more and more easy to record
+ many variables at the same time
(more than 50 variables)
+ with large sampling frequency
(more than 50 Hz)
+ with long durations
+ in many recording situations
(through either an experimental
or observational design with many
factors and participants)
+ ...

III. The first stage: Data characterization

Why space-windowing ?

=> 1) database that is

*** Very large**

*** Very complex :**

- many physical scales

(m, m/s, m/s/s, N, volt, °, %s...) and,
in most cases

- two mathematical scales

(quantitative and qualitative)

III. The first stage: Data characterization

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- two mathematical scales
(quantitative and qualitative)

2) database where

it is more and more easy to have

- human errors

- measurement device errors

III. The first stage: Data characterization

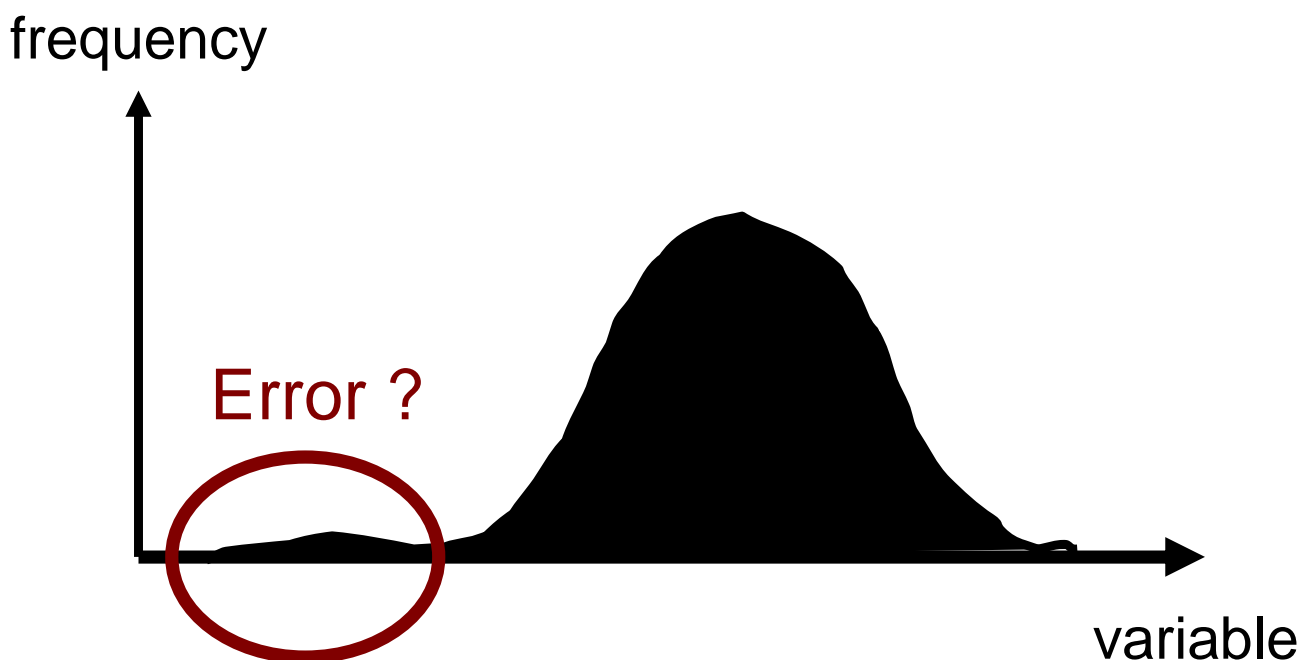
Why space-windowing ?

With a given time variable
the magnitude histogram is
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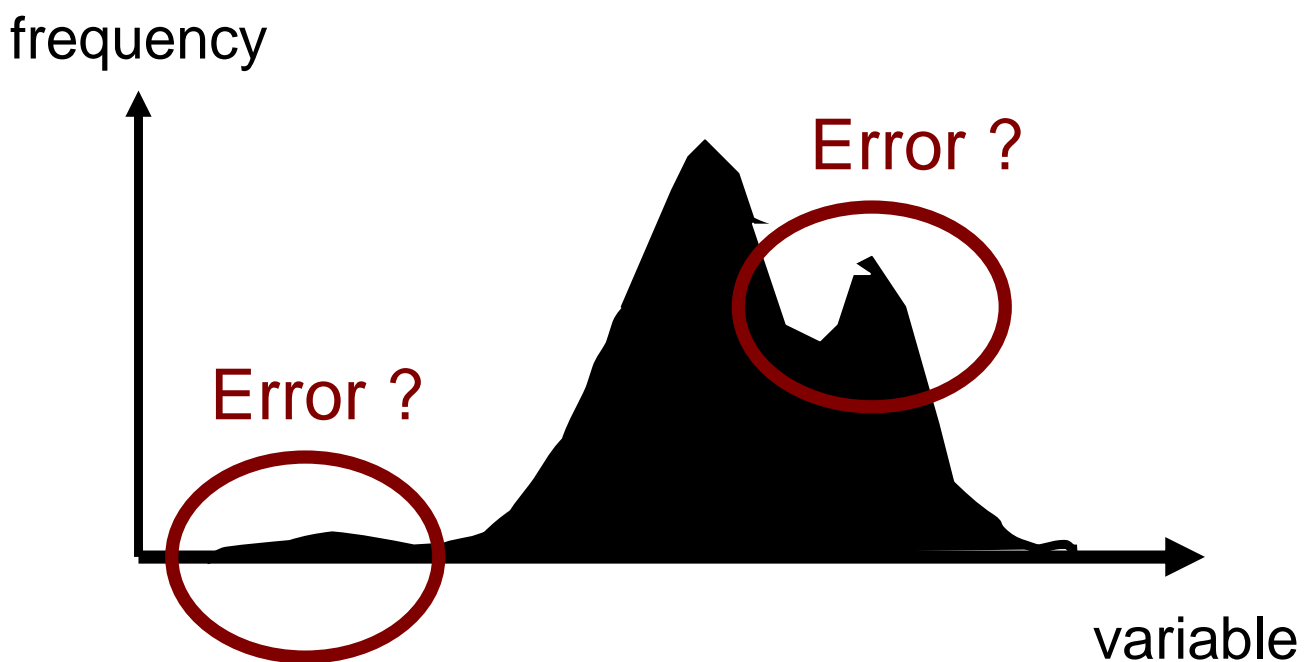
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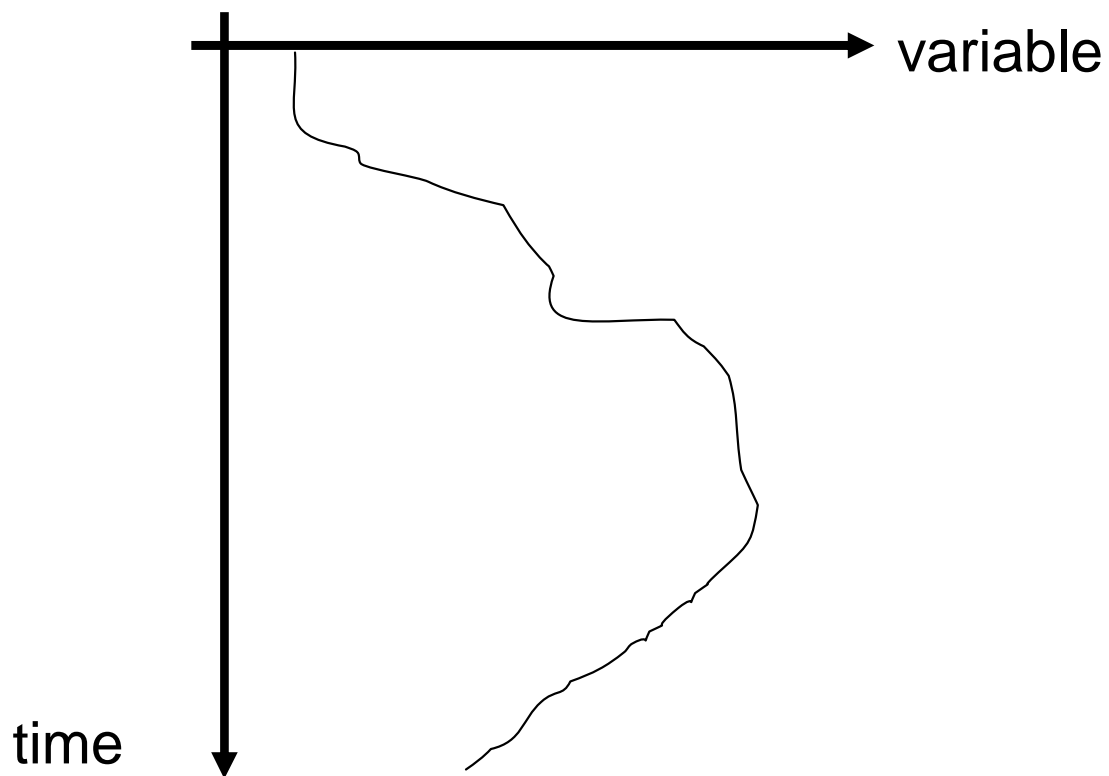
With one time variable
the magnitude histogram is
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III. The first stage: Data characterization

Why space-windowing ?

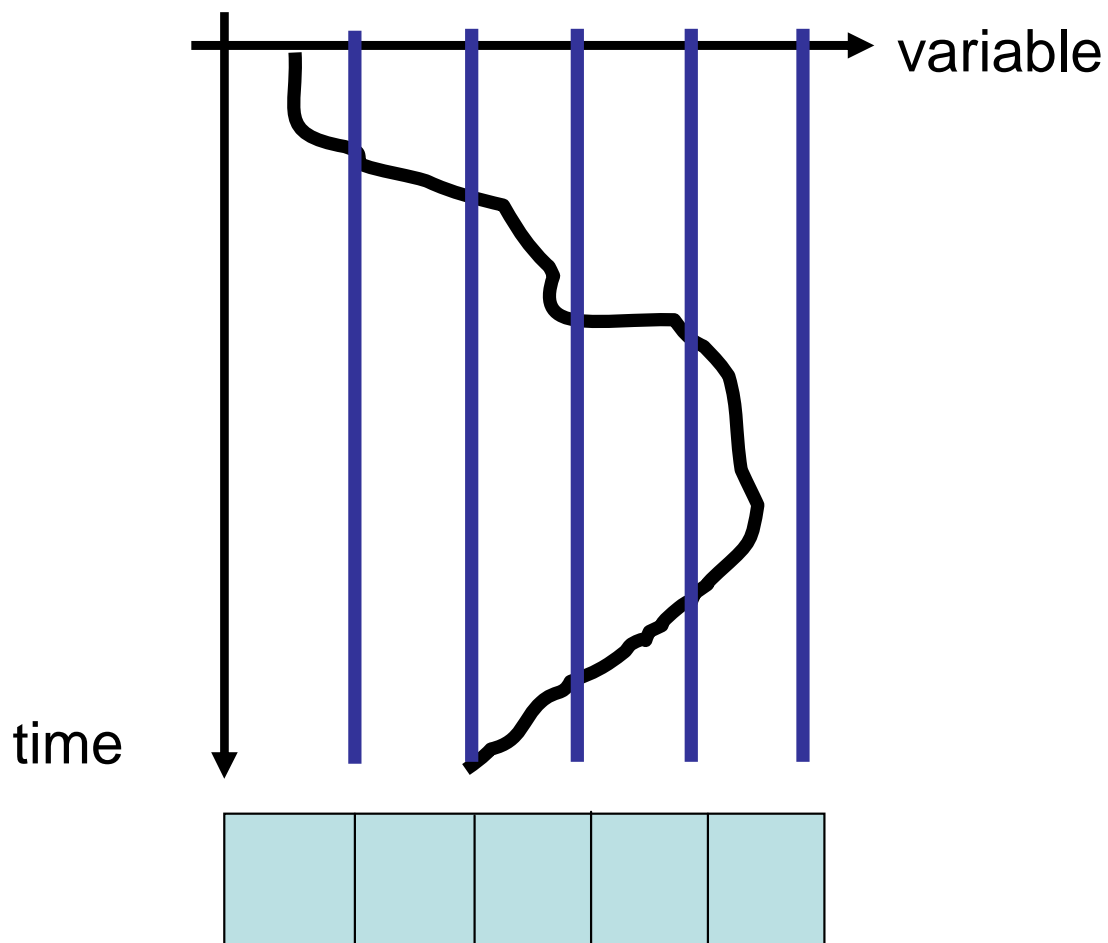
With one time variable



III. The first stage: Data characterization

Why space-windowing ?

With one time variable

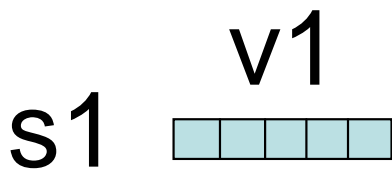


A set of
Membership Value Averages
(MVA)

III. The first stage: Data characterization

Why space-windowing ?

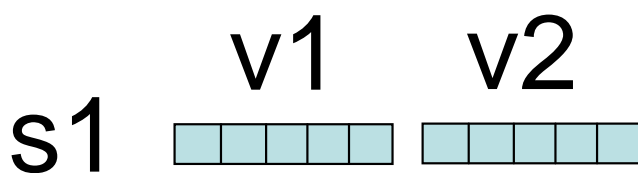
With many
time variables v_1, v_2, \dots
empirical situations s_1, s_2, \dots



III. The first stage: Data characterization

Why space-windowing ?

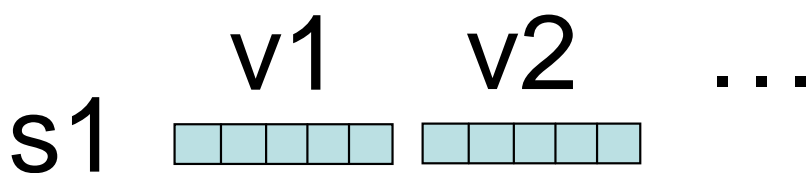
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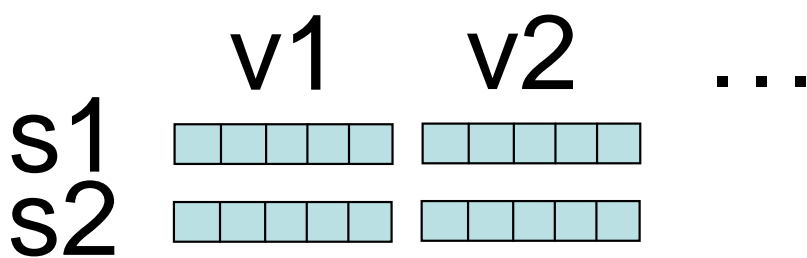
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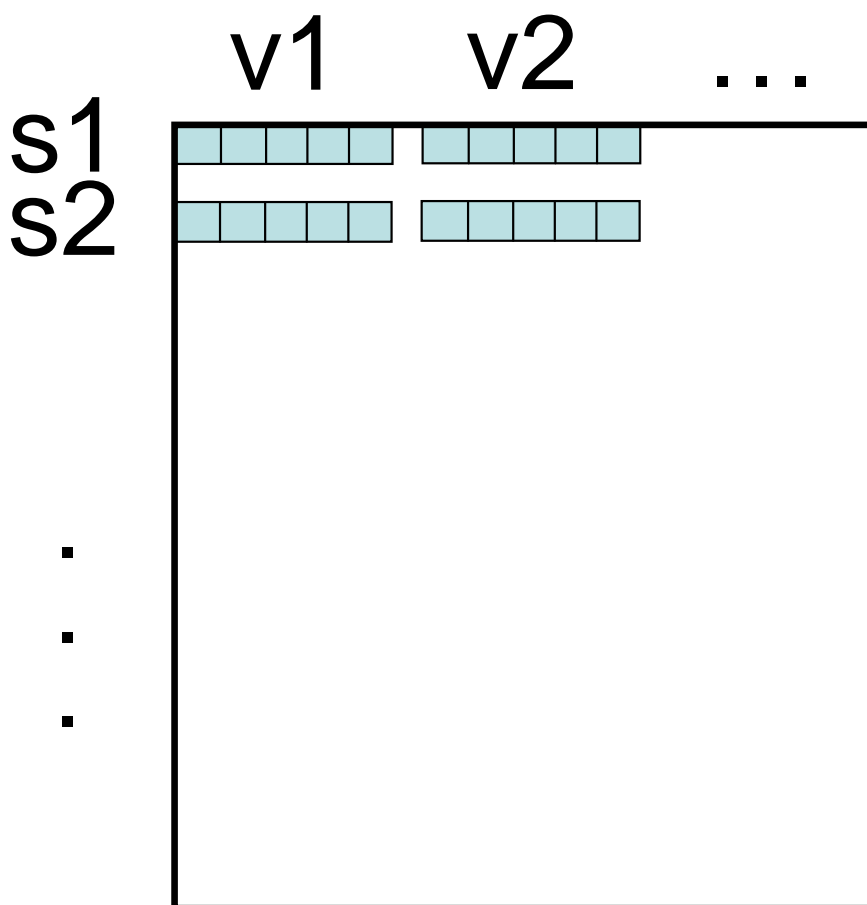
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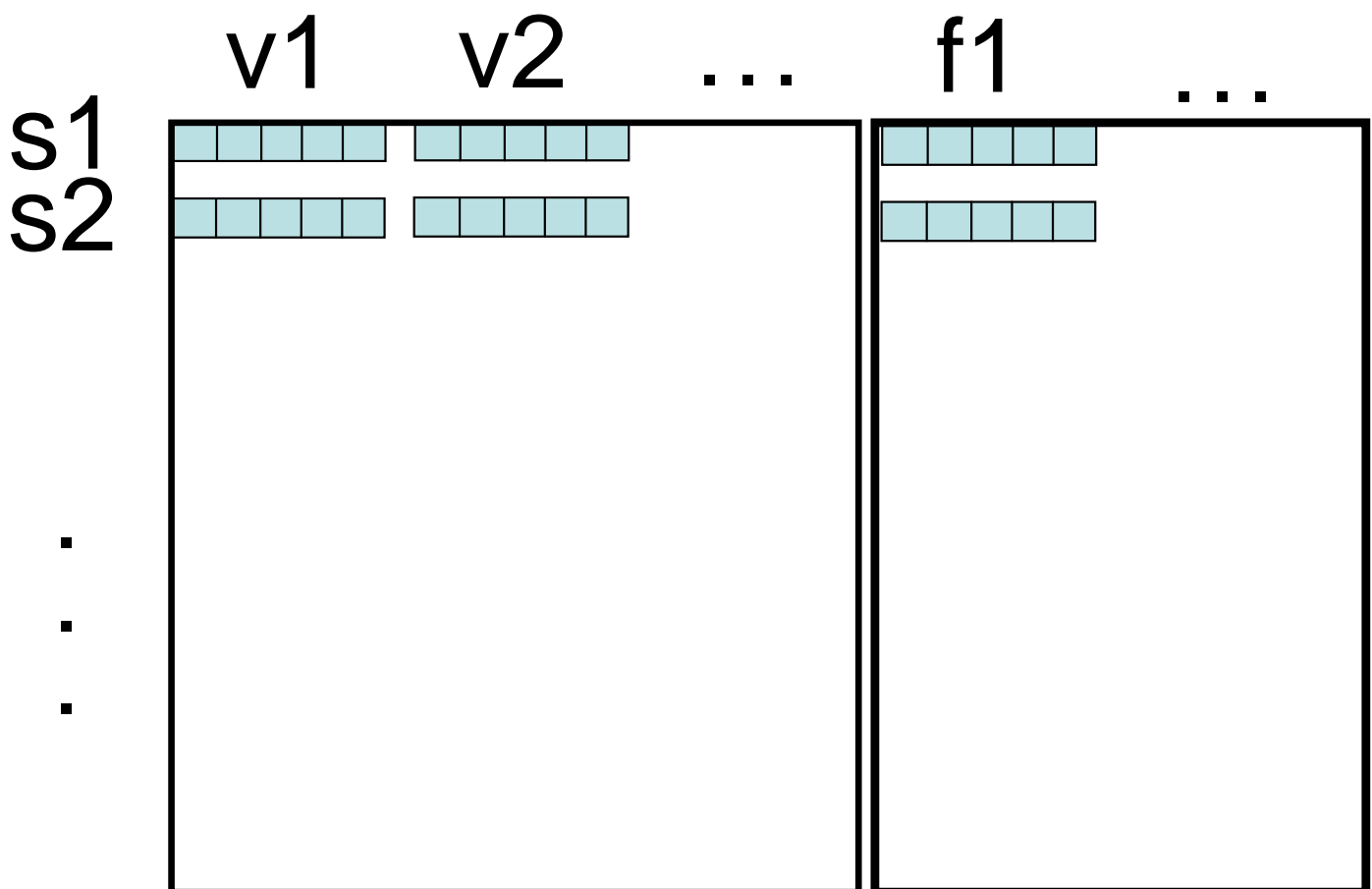
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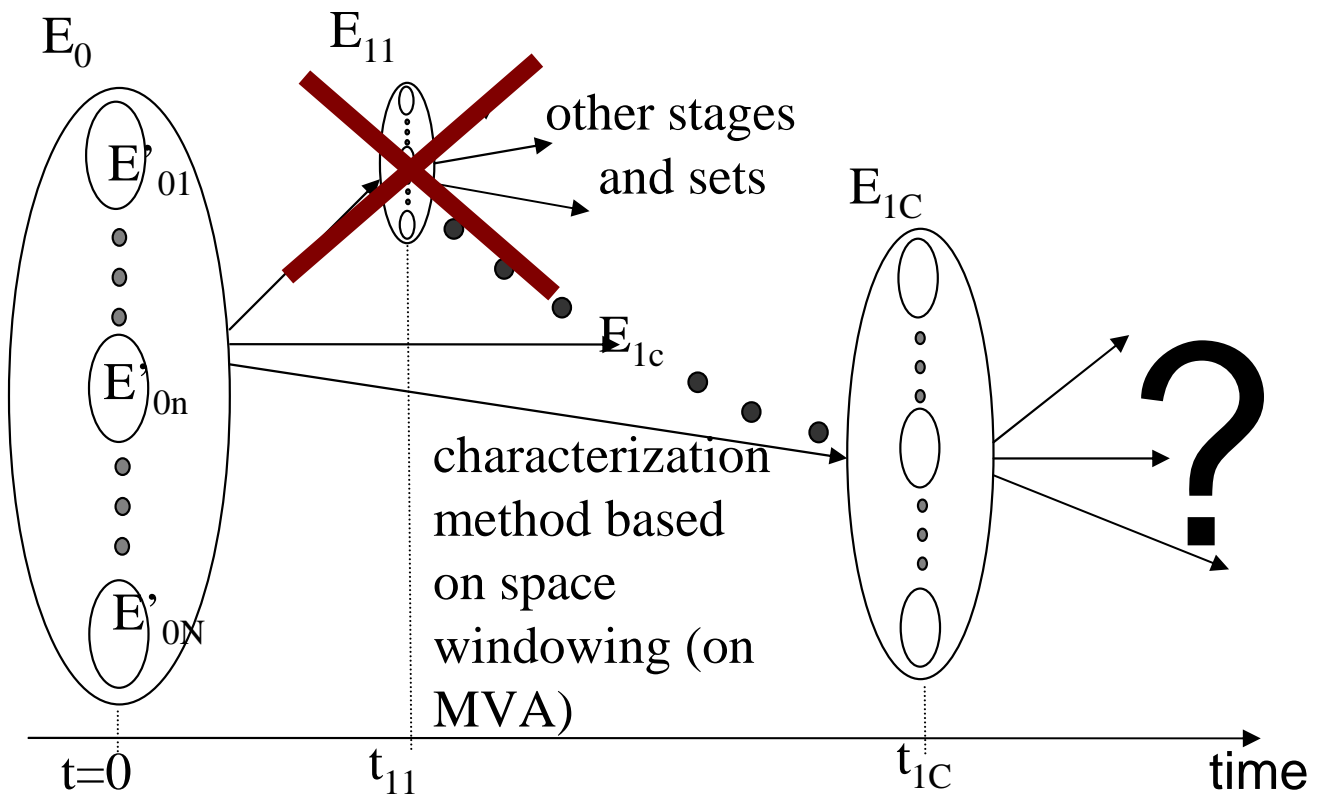
III. The first stage: Data characterization

Why space-windowing ?

With many
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IV. The subsequent analysis



IV. The subsequent analysis

With MVA, there are 2 main families of analysis paths:

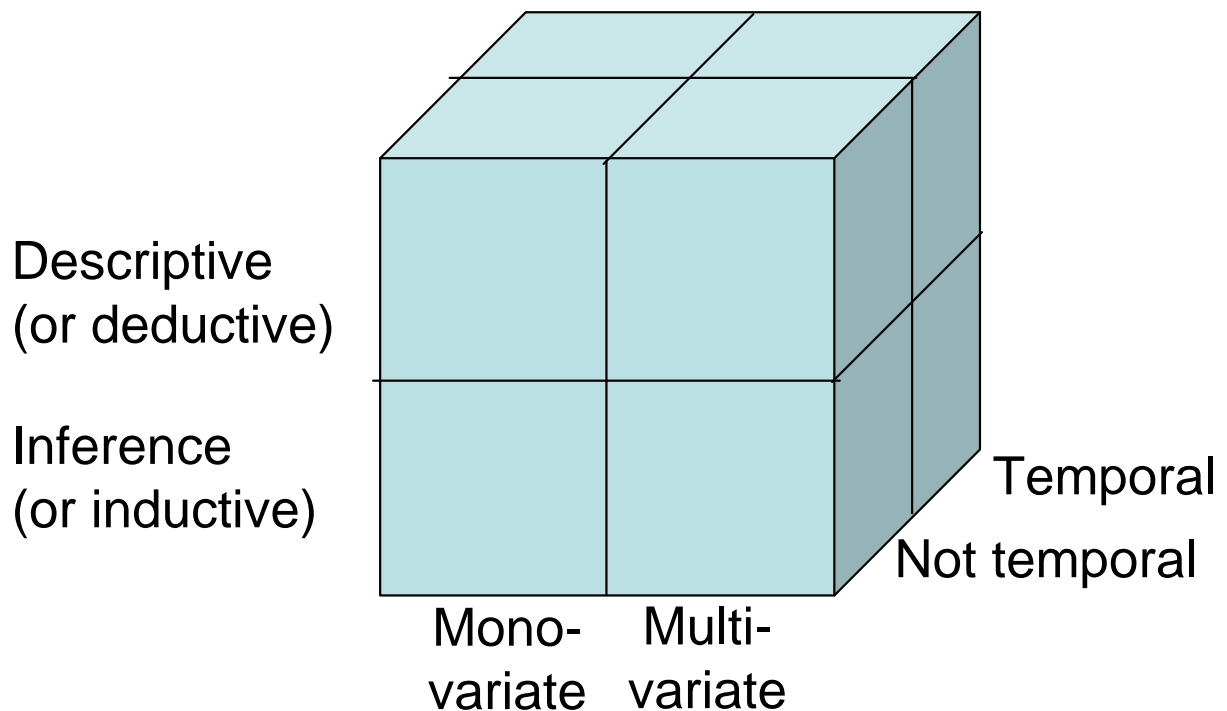
- Based on fuzzy set theory, i.e. with operators min and max

IV. The subsequent analysis

With MVA, there are 2 main families of analysis paths:

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- Based on statistics, i.e. with chi-squared used in

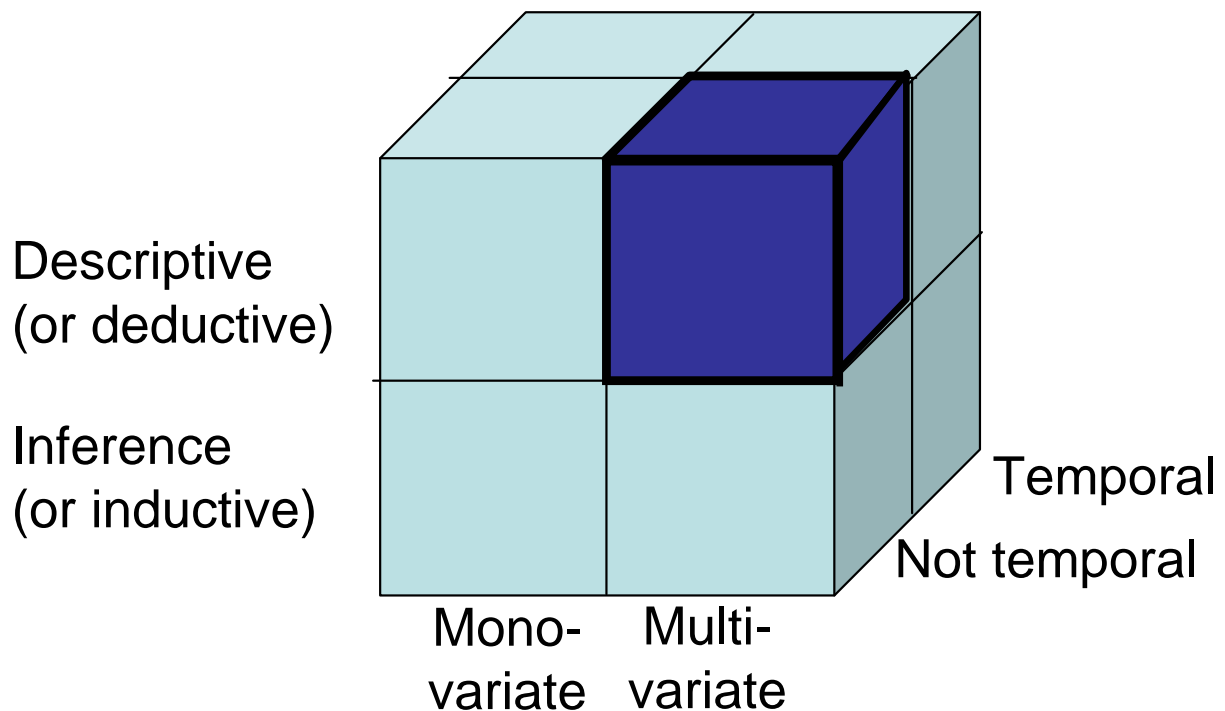


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 - classification and grouping

 - factor analysis e.g.

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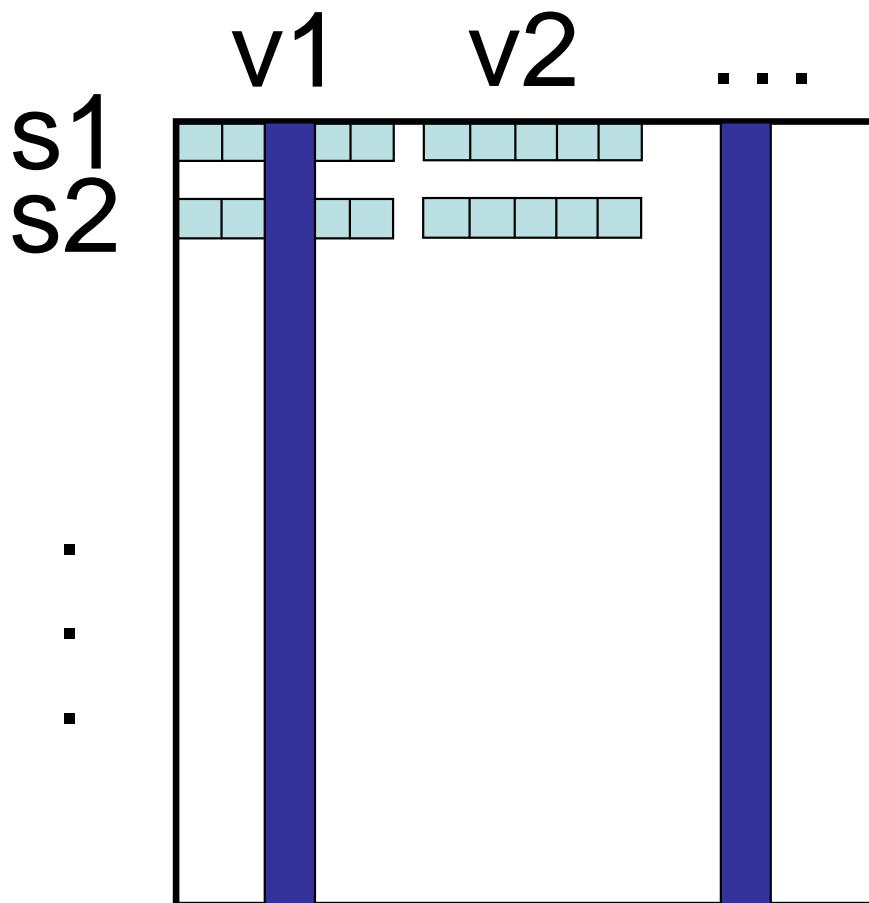
 - classification and grouping

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Multiple Correspondence Analysis (MCA)

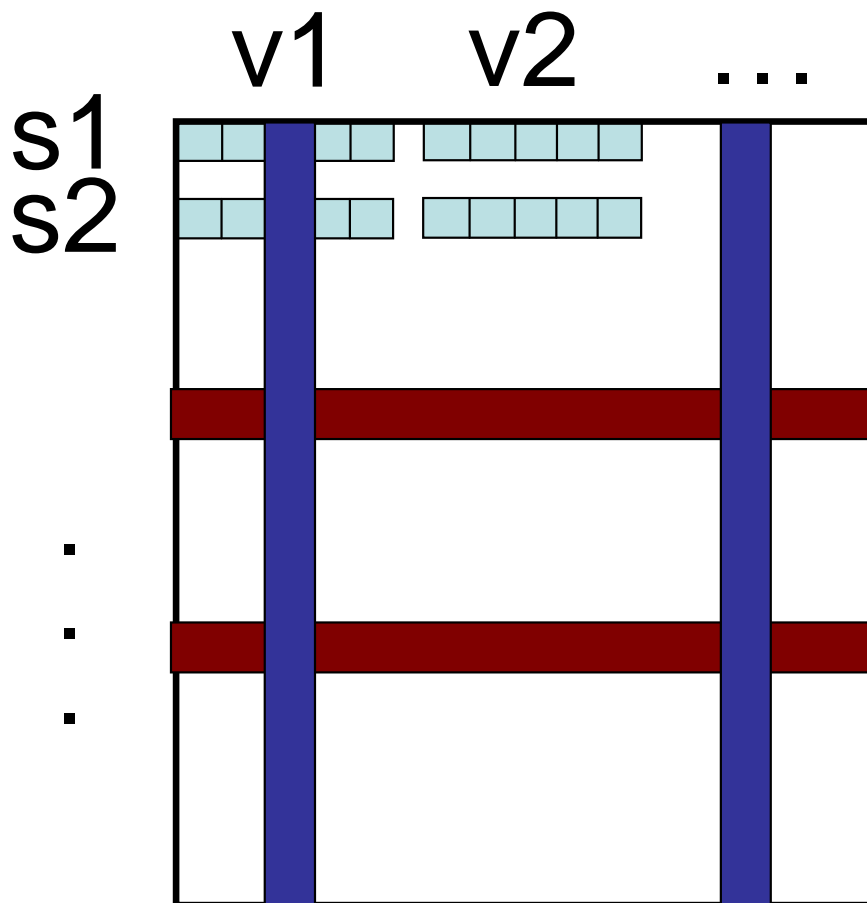
IV. The subsequent analysis

grouping



IV. The subsequent analysis

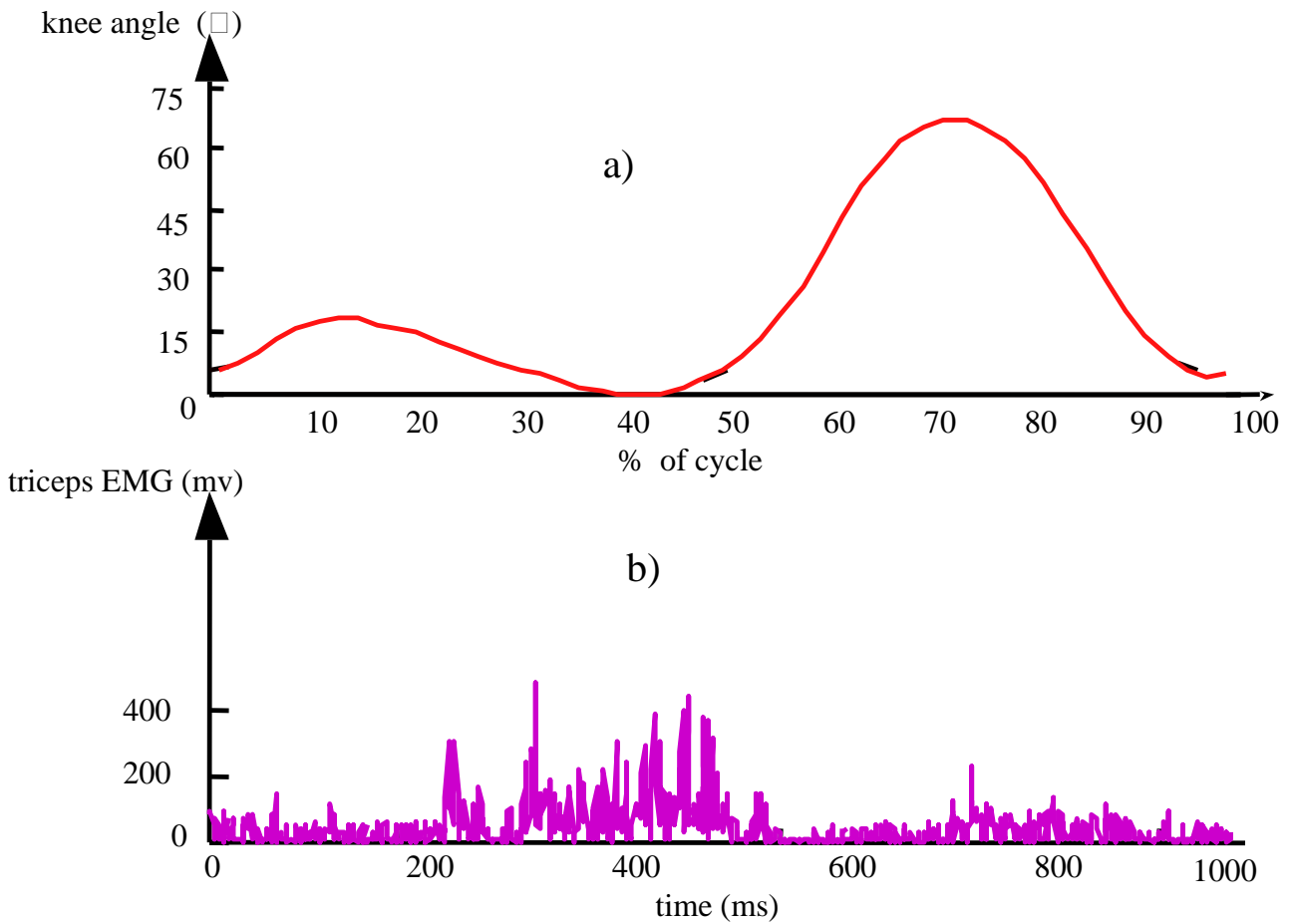
Factor analysis (MCA)



IV. The subsequent analysis

Example : pathological gait

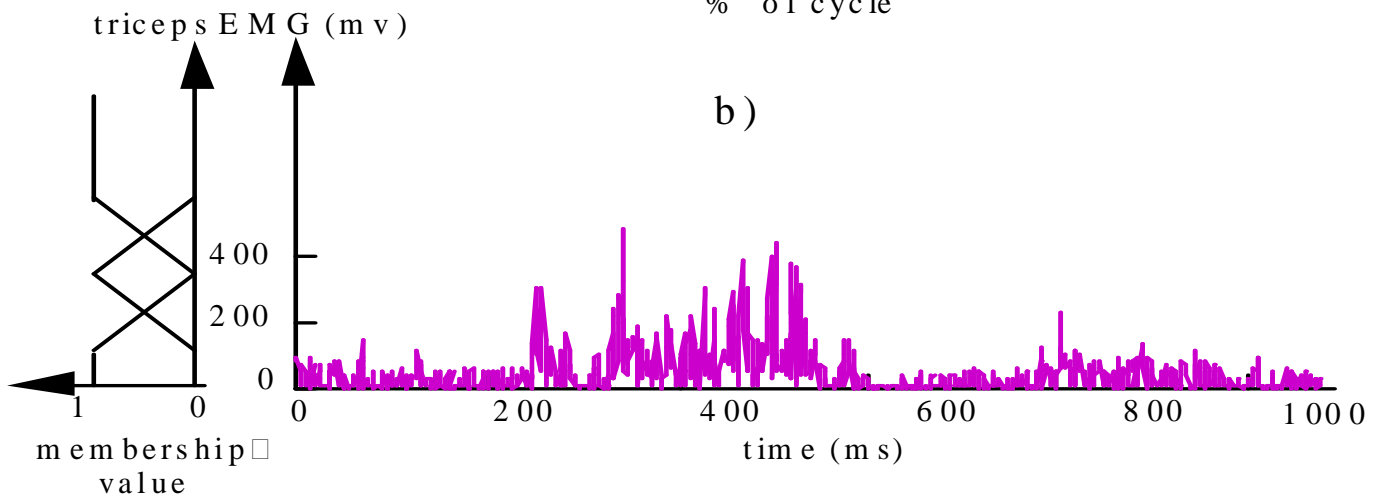
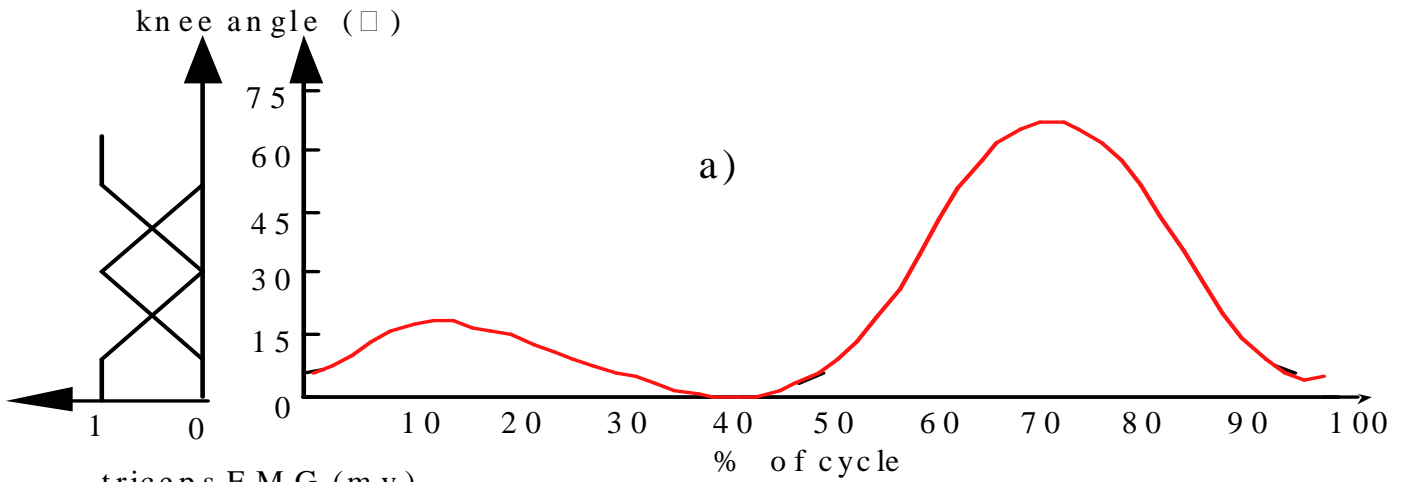
1) Data characterization



IV. The subsequent analysis

Example : pathological gait

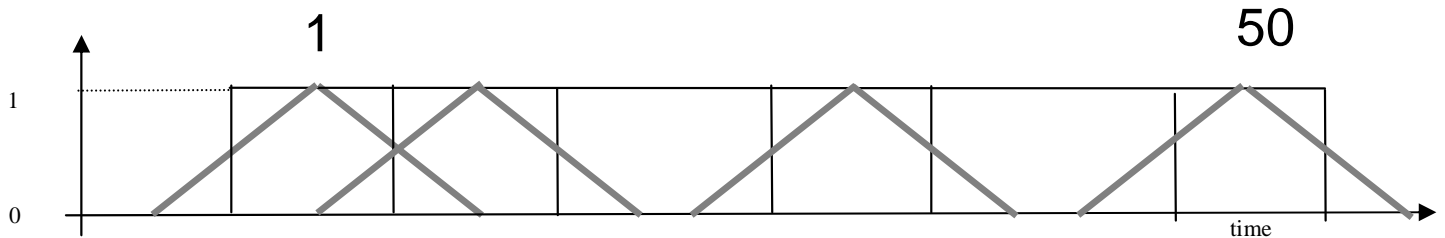
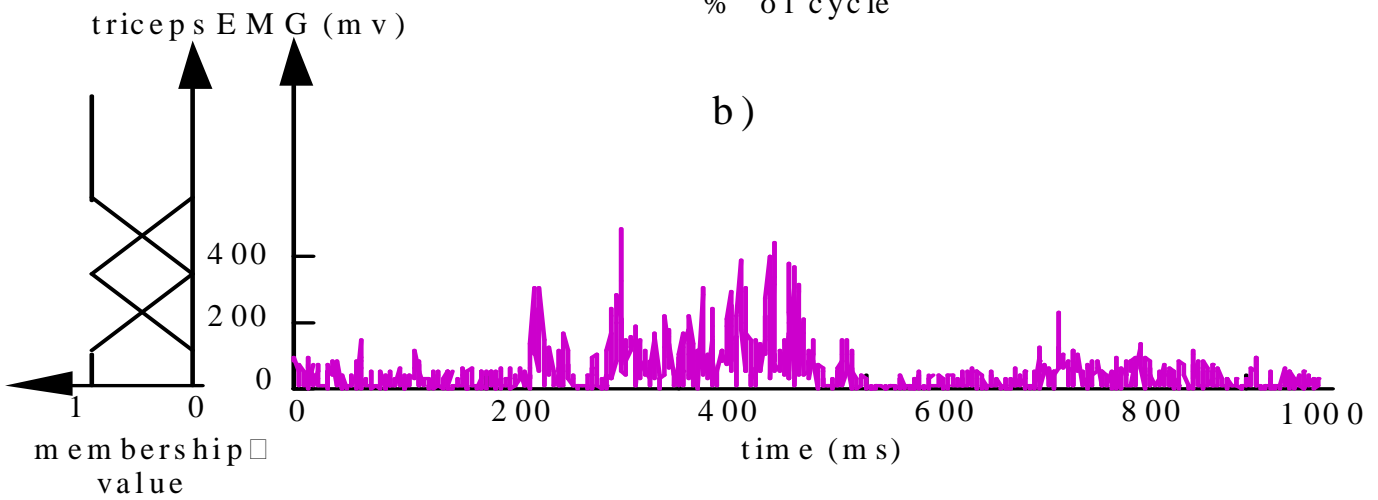
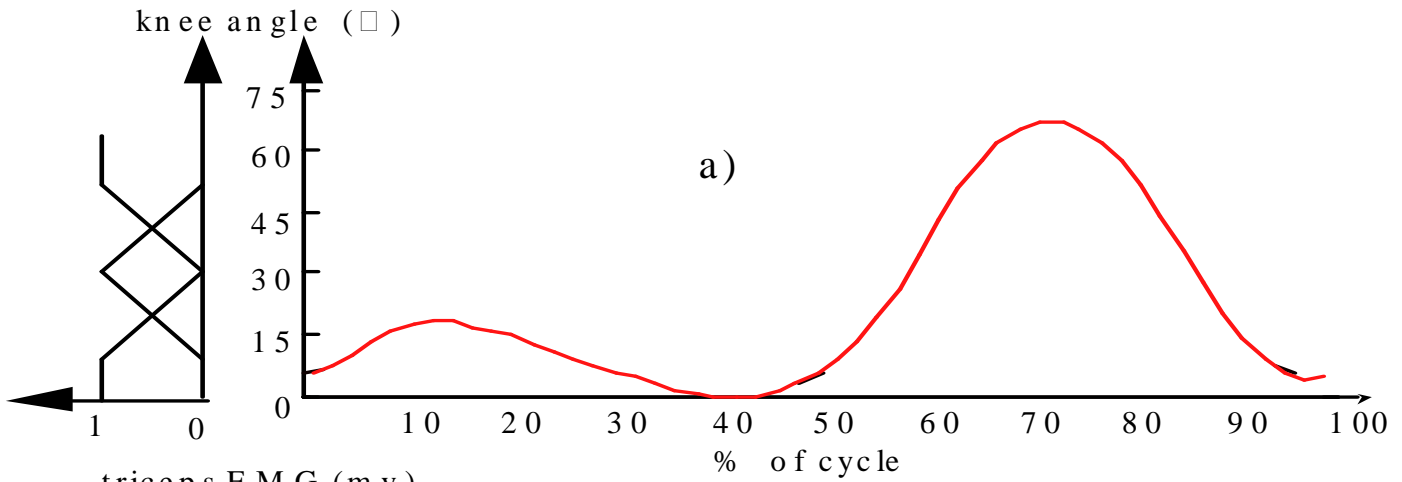
1) Data characterization



IV. The subsequent analysis

Example : pathological gait

1) Data characterization

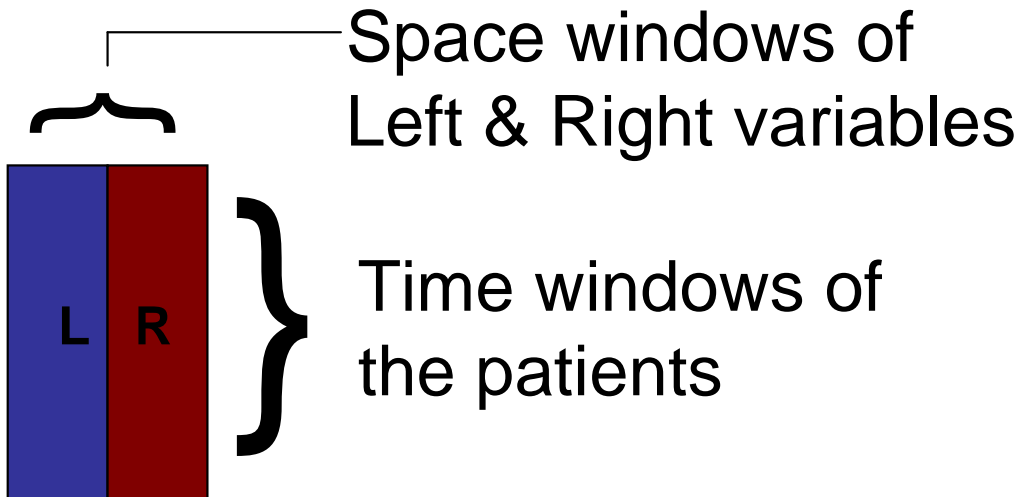


IV. The subsequent analysis

Example : pathological gait **2) Data coding**

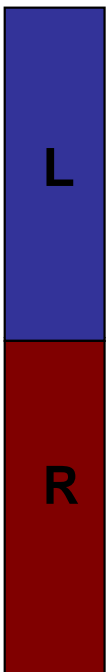
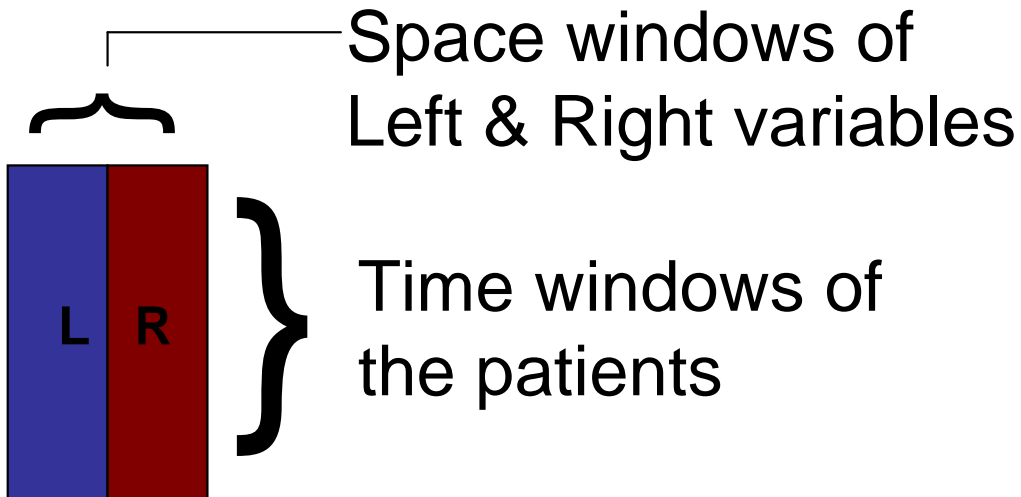
IV. The subsequent analysis

Example : pathological gait 3) Data shaping



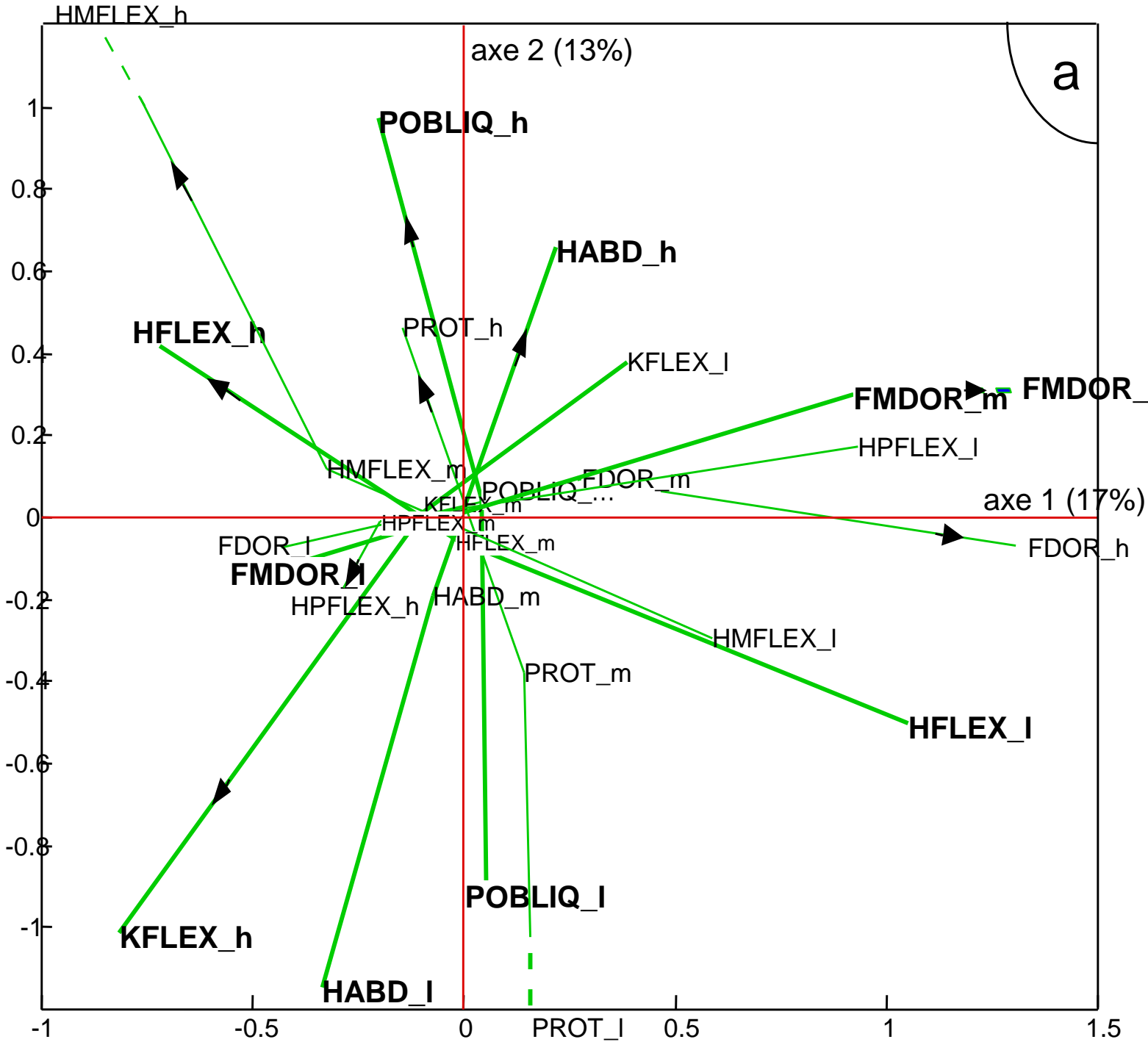
IV. The subsequent analysis

Example : pathological gait 3) Data shaping



IV. The subsequent analysis

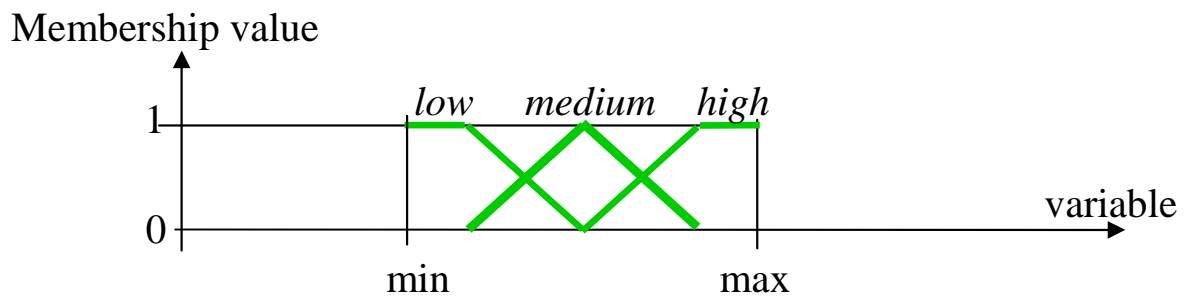
Example : pathological gait 4) Analysis of relationships and classes



IV. The subsequent analysis

Example : pathological gait

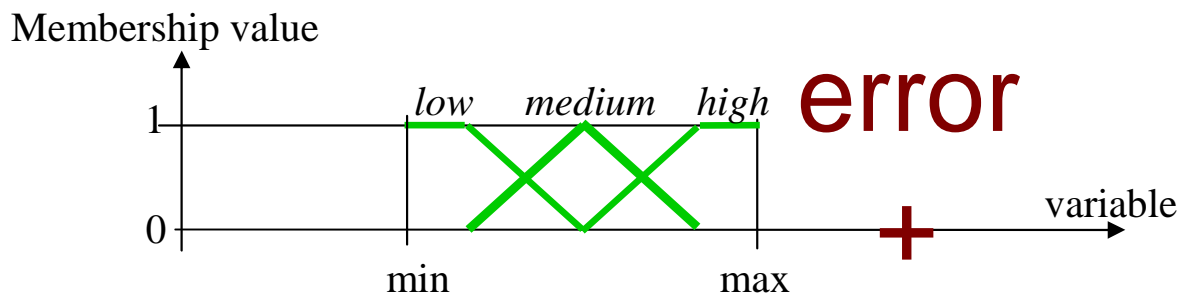
4) Analysis of relationships and classes



IV. The subsequent analysis

Example : pathological gait

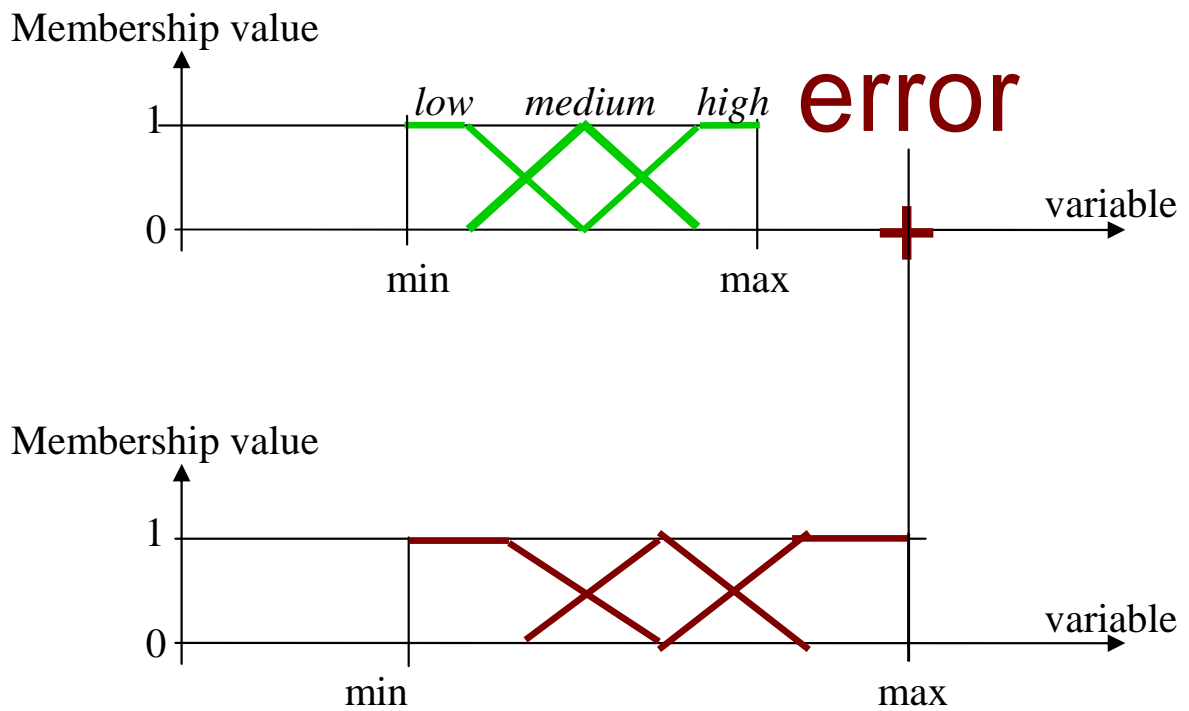
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IV. The subsequent analysis

Example : pathological gait

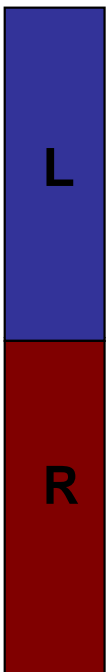
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IV. The subsequent analysis

Example : pathological gait

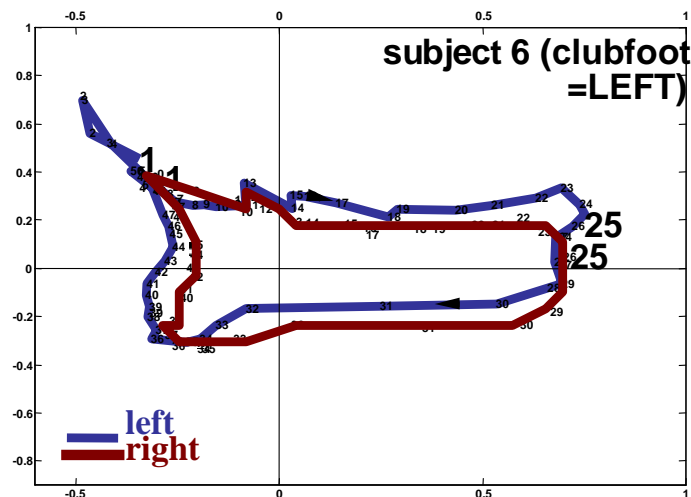
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IV. The subsequent analysis

Example : pathological gait

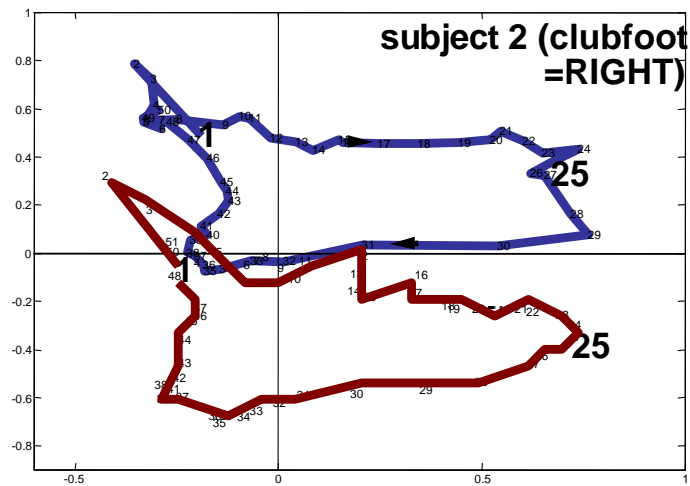
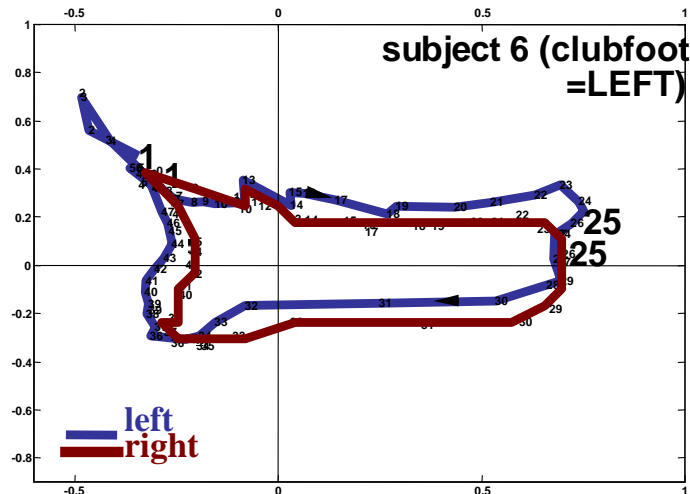
4) Analysis of relationships and classes



IV. The subsequent analysis

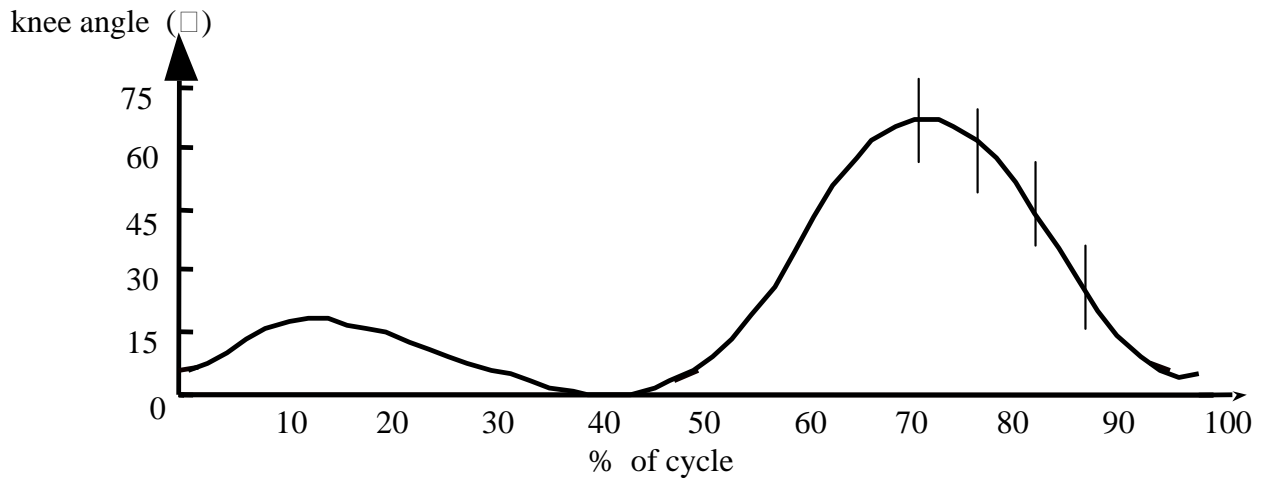
Example : pathological gait

4) Analysis of relationships and classes



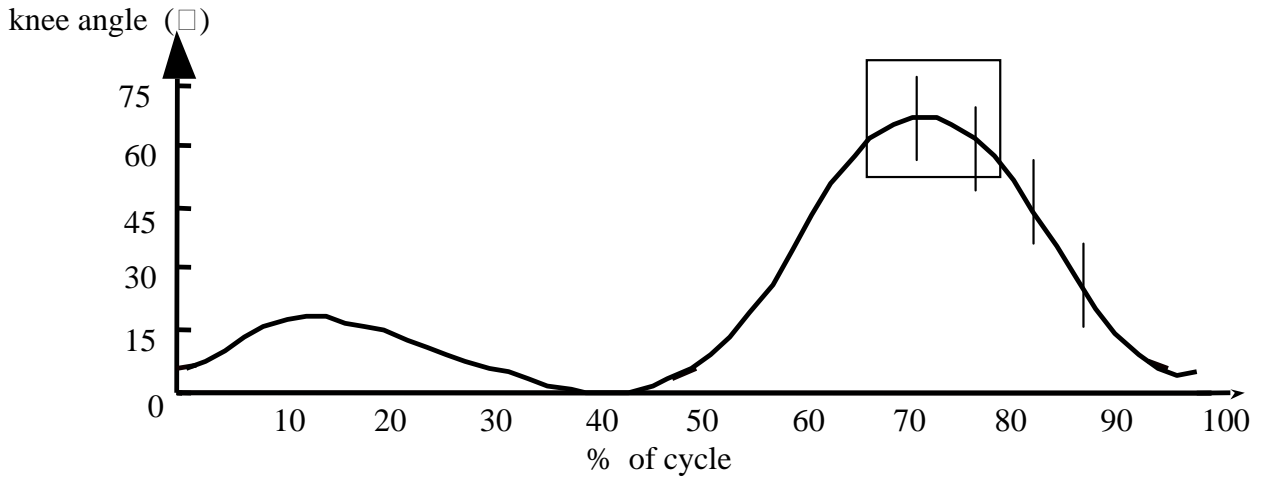
IV. The subsequent analysis

Example : pathological gait 5) Result presentation

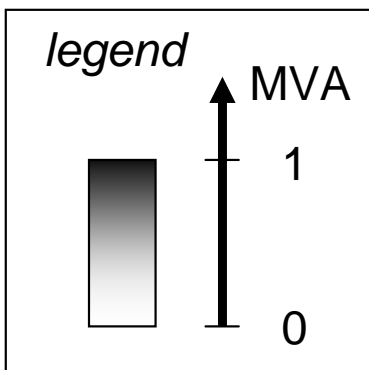
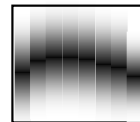


IV. The subsequent analysis

Example : pathological gait 5) Result presentation

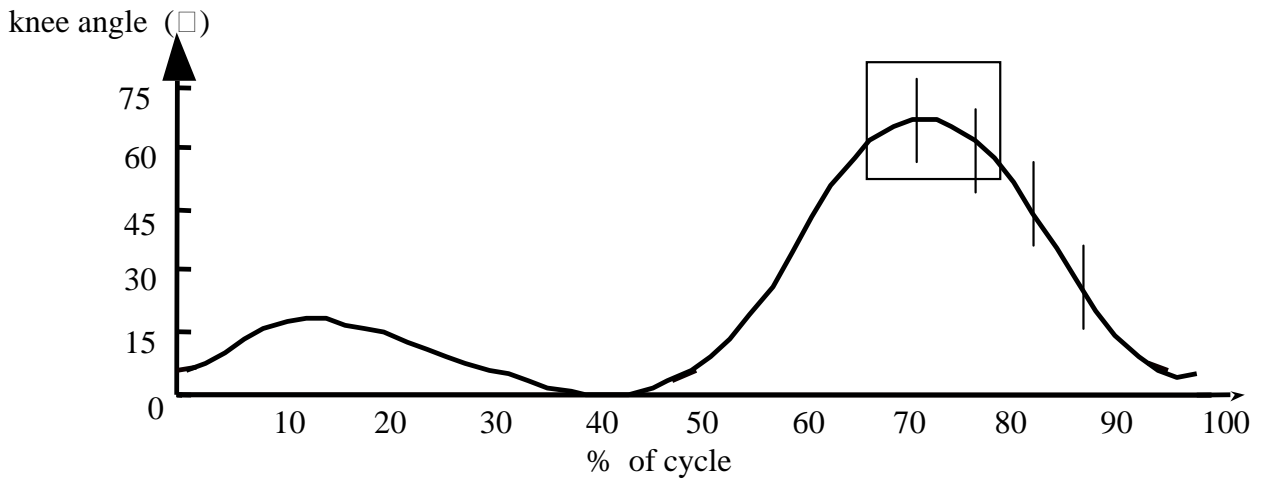


1 class

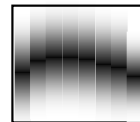


IV. The subsequent analysis

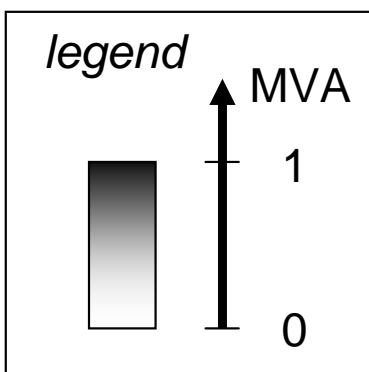
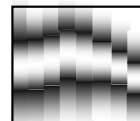
Example : pathological gait 5) Result presentation



1 class



2 classes



V. Conclusion

About the Multivariate aspect

time data

Not time data

Quantitative
scale

3D
biom.
data

Qualitative
scale

V. Conclusion

About the Multivariate aspect

time data

Not time data

Quantitative scale	Arithmetic mean Standard deviation ...	
Qualitative scale		

V. Conclusion

About the Multivariate aspect

time data

Not time data

Quantitative scale	Arithmetic mean Standard deviation ...	Arithmetic mean Standard deviation ...
Qualitative scale		

V. Conclusion

About the Multivariate aspect

time data

Not time data

Quantitative
scale

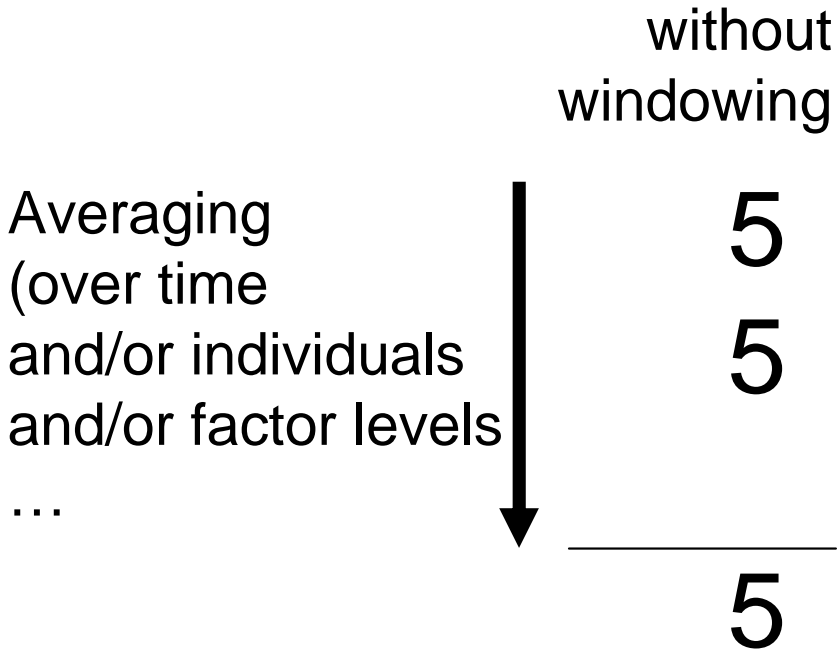
Space

windowing

Qualitative
scale

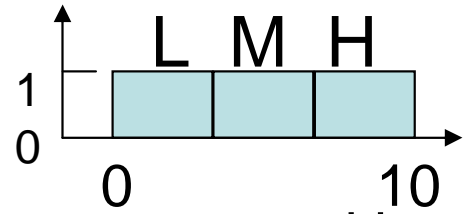
V. Conclusion

About the averaging aspect



V. Conclusion

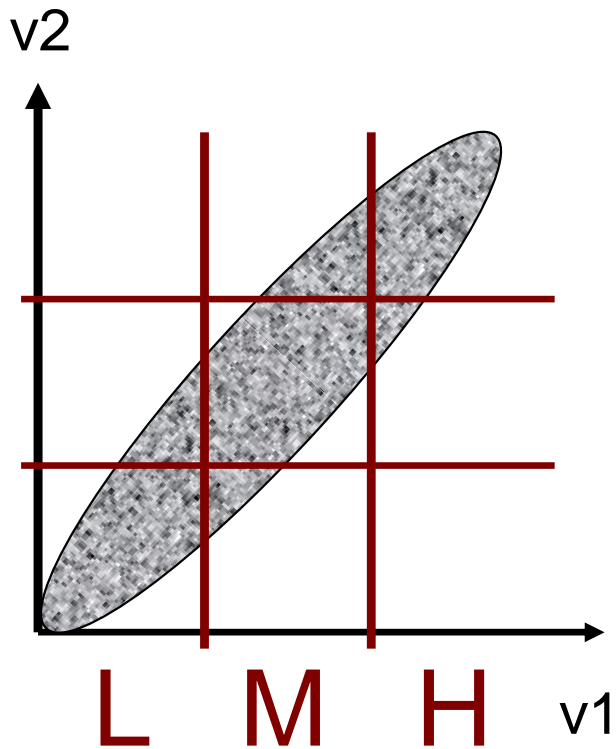
About the averaging aspect



	without windowing	with windowing		
Averaging (over time and/or individuals and/or factor levels ...)	5	0	1	0
	5	0	1	0
	<hr/> 5	<hr/> 0	<hr/> 1	<hr/> 0

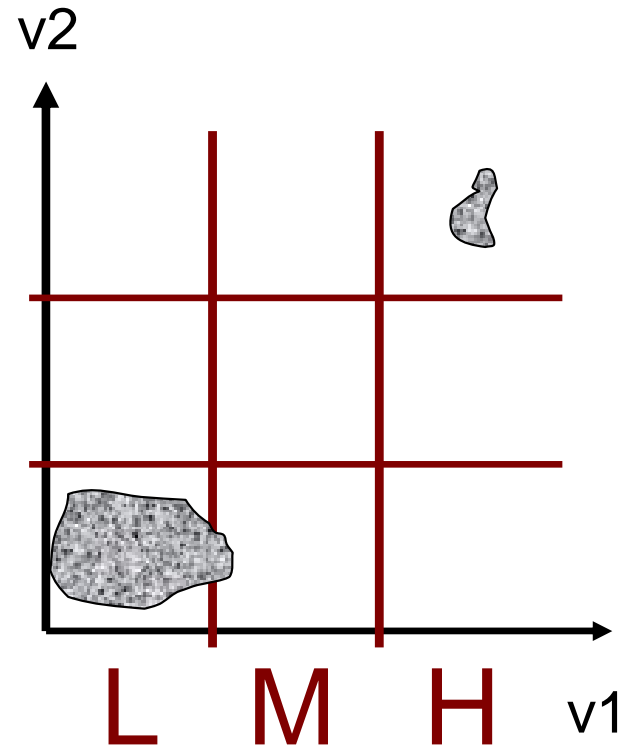
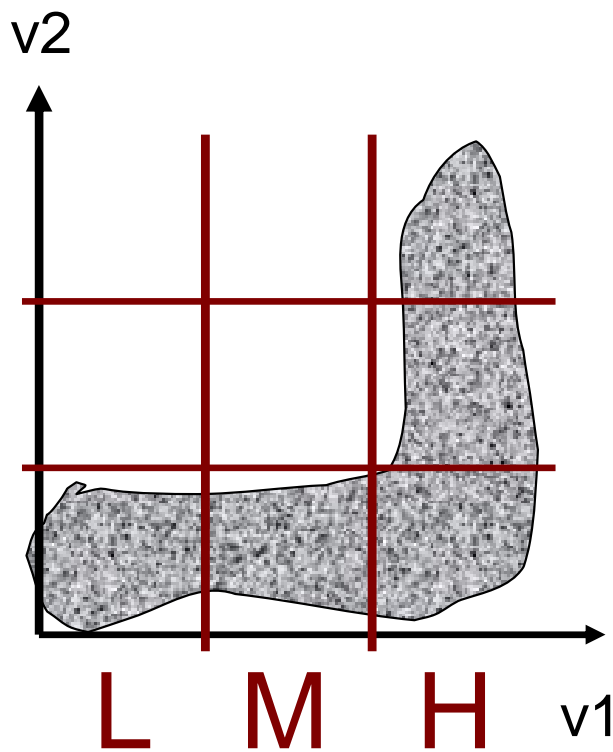
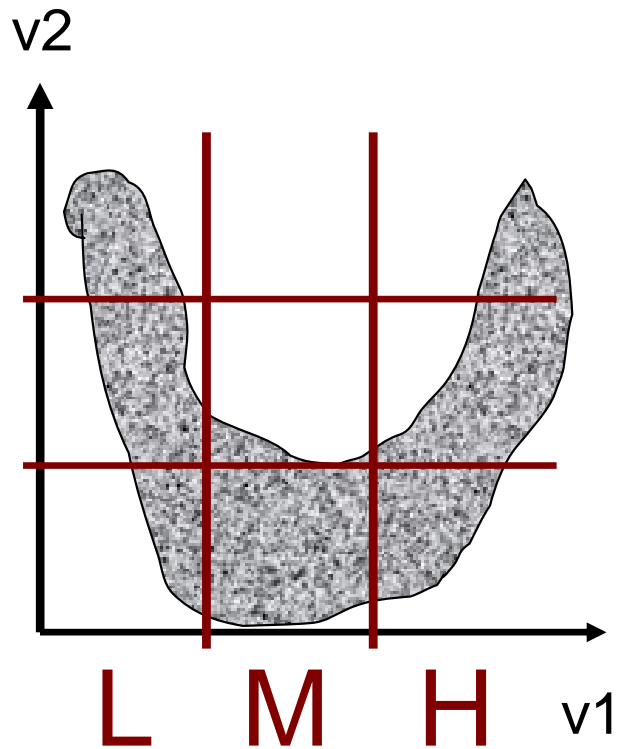
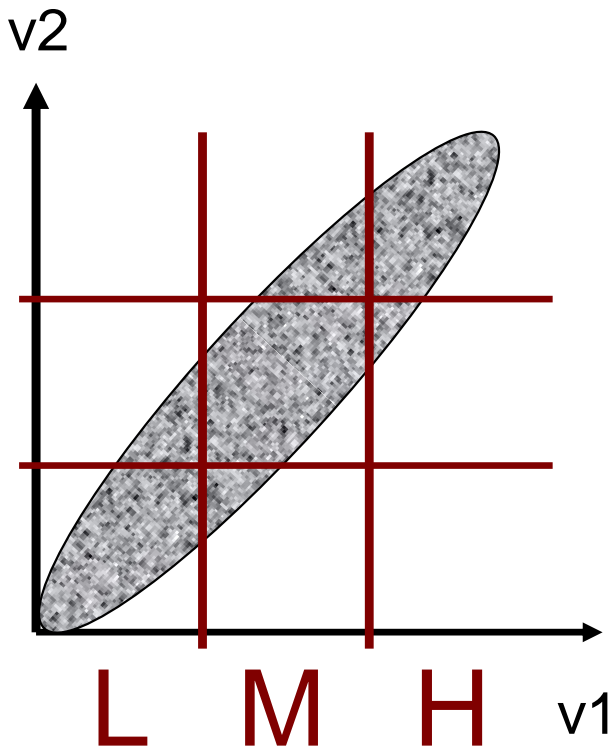
V. Conclusion

About the relational aspect



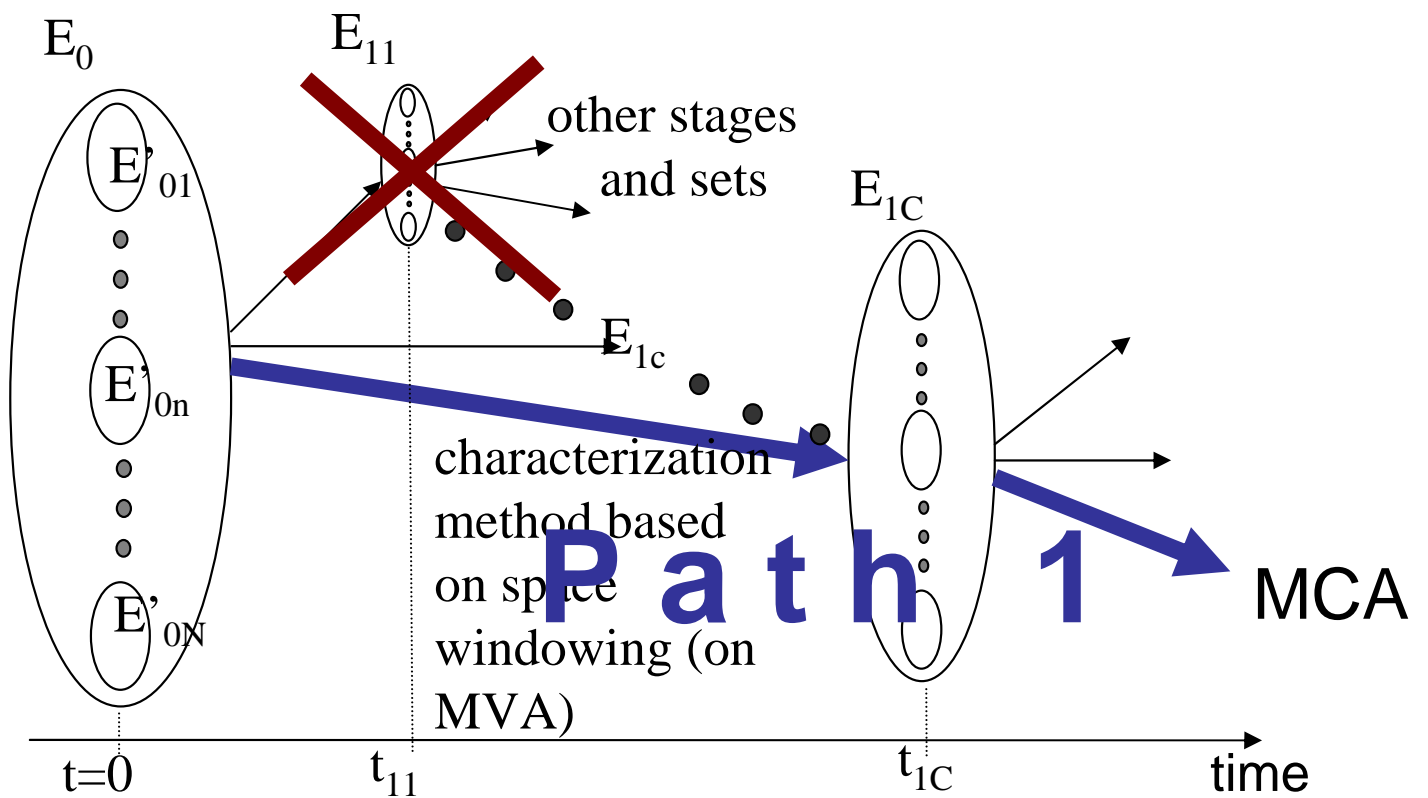
V. Conclusion

About the relational aspect

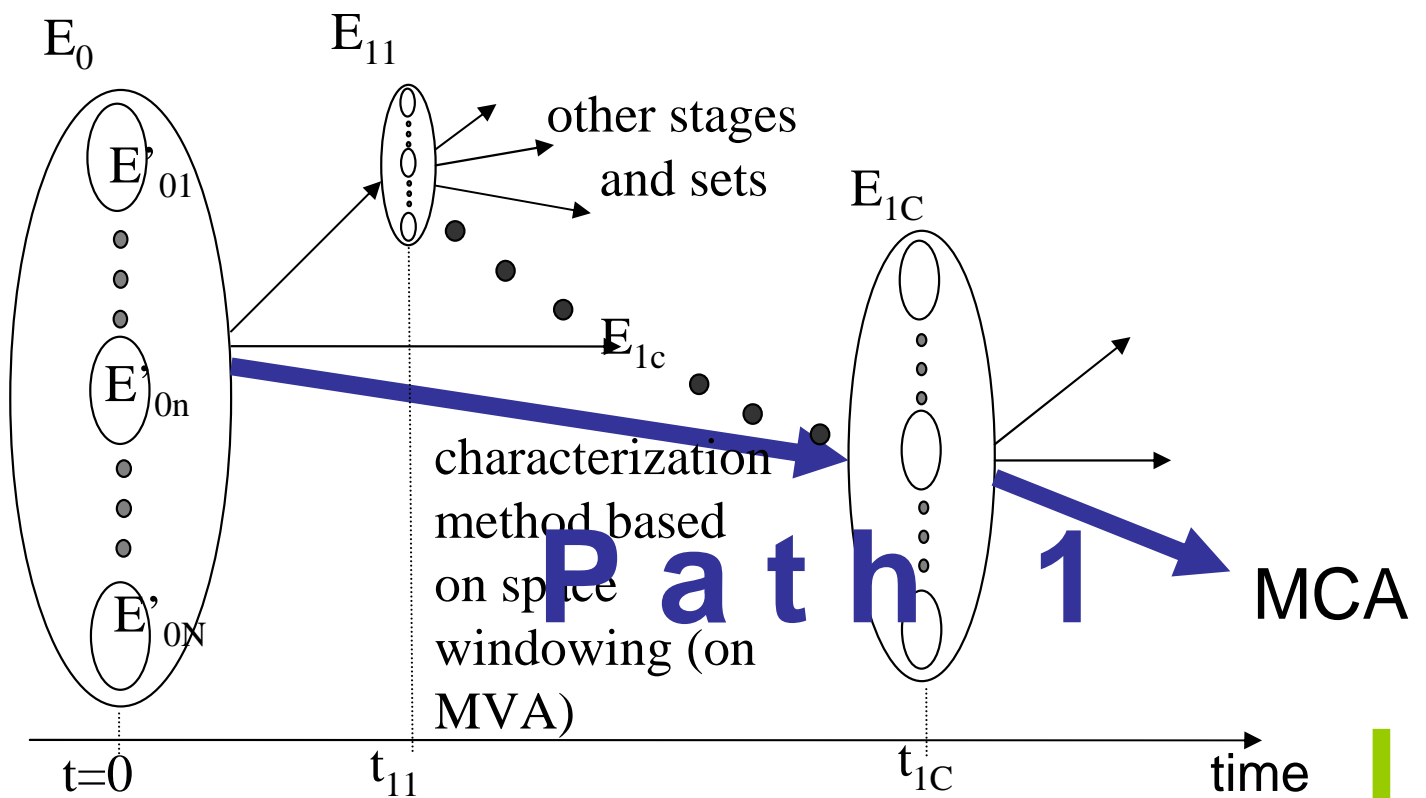


V. Conclusion

About the next paths



V. Conclusion About the next paths



Further investigation

V. Conclusion

About the next paths

