Understanding Dataset

elements of science misbehaviour

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with a strong support of Arnaud Legrand

LIG
Grenoble – November 2020

DATA STATISTICS INTRODUCTION

1. CAUSALITY : The Question

2. DATA SET : A so Simple Object
   - THE PROBLEM : Building of data set
   - SET OF VARIABLES
   - TYPES OF VARIABLES
   - ROLE OF VARIABLES

3. THE PROBLEM : The Data Set
   - THE PROBLEM : How data were produced
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   - MISSING VALUES

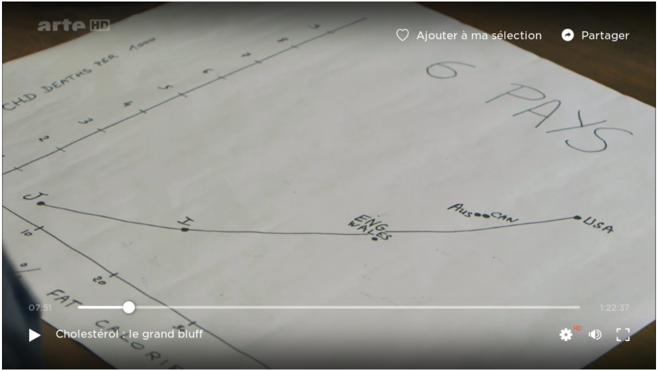
4. EXPLORATIONS
   - ANALYSIS OF DATASET
   - SAMPLE ANALYSIS
   - CENTRAL TENDENCY
   - VARIABILITY

5. SYNTHESIS

UNIVERSITÉ Grenoble Alpes

A vivid debate : Cholesterol and Statins

Cholesterol: le grand bluff (Arte, 18/10/2016 @ 20h50)



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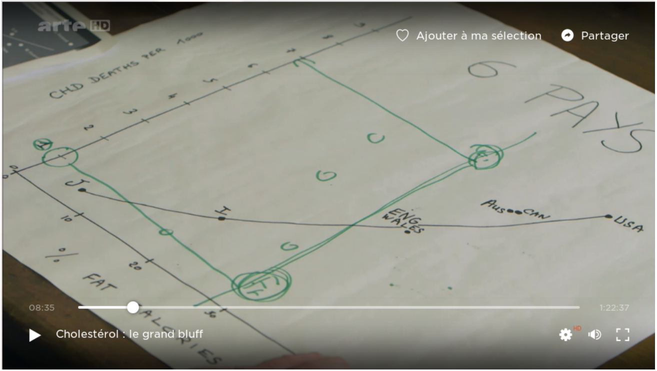

"Careful" selection of data and influence from the industry

What happens ?

SCIENTIFIC FACTS

Scientific Hypothesis

- A **Theory** is a contemplative and rational type of abstract or generalizing thinking about a phenomenon, or the results of such thinking (wikipedia)
- **Falsifiability** is the logical possibility that an assertion can be shown false by an observation or a physical experiment. [Popper 1930]

Observations

Data set produced by an experiment (or a survey)

- Experimental Design (lectures of SMPE)
  the design is driven by the scientific question
- Existing Data
  the scientific question is driven by the Dataset

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Data Production

First question : Why this dataset has been produced ? (purpose)

- Who organized the study ?
- What was the question to be answered by the statistical analysis ?
- Who will be the target of the analysis ?

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- Exhaustive collected information
- Designed survey on a population
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- Designed Experiments

Third question : How this dataset has been practically produced ? (observations)

- Nature of the items in the Data set
- Characterization of data
- Semantic of Data

Take time to analyse the production process

ANALYSIS OF THE SET OF VARIABLES

Identification of the variables types

- Type of the variables (numbers, identifiers, ...)
- Set of values taken by the variables (bounds, sets,...)
- Properties of the variables (positive,...)

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- When these variables has been collected ?
- Why these variables have been chosen ?

Analysis of the Set of Variables

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- Properties of the variables (positive,...)

Identification of the variables role

- When these variables has been collected ?
- Why these variables have been chosen ?

Identification of the variables semantic

- What is the interpretation of the variables values ? (size, weight, ...)
- What are the relations between variables (structure) ?

Take time to build a serious metadata document

Analysis of the Type of Variables

Nominal Variables : classification, membership (qualitative)

- Values in an unstructured set
- Examples : color, gender, ...
- Methods : grouping
- Operators : $=, \neq$

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Quantitative Variables : Quantities

- Real values (ratio is significant)
- Examples : amount, duration, cost ...
- Methods : sum, difference
- Operators : $+, -, (\times, /)$

Take time to define precisely the variables properties

Usage of Variables

Response Variables

- Quantity asked by the question
- Examples : response time, iteration duration, ...

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Univariate or Multivariate

- Univariate : one variable is involved
- Multivariate : several variables are involved

Take time to identify the response/explanatory variables

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DATA PRODUCTION PROCESS

Global Process

Question $\Longrightarrow$ Experiment, Survey $\Longrightarrow$ Decision

Decision = Risk

DATA PRODUCTION PROCESS

Global Process

Question ⟹ Experiment, Survey ⟹ Decision

Decision = Risk

Quality of Data

Specification of the Data

- Error model for the values
- Experimental/Survey bias
- Analysis limitations

Evaluate the Quality of the Decision

CRITERIA FOR THE QUALITY OF DATA (FROM EUROSTAT)

Relevance

- degree to which statistics meet current and potential needs
- could extend to varying needs

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Accuracy

- Closeness of computations or estimates to the (unknown) exact or true values
- Variability (random error) and bias (systematic error)
- Sources of errors (experimental, coverage sampling...)

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Timeliness

- delay between the reference point and the availability date
- trade-off against accuracy,

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- measuring the impact of differences in applied statistical concepts and measurement tools/procedures when statistics are compared between geographical areas, non-geographical domains, or over time

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- adequacy to be reliably combined in different ways
- compatibility of measures

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Accessibility

- Accessibility refers to the physical conditions under which users can obtain data
- Clarity refers to the data's information environment

Extracted from *Handbook on Data Quality Assessment Methods and Tools* EuroStat Report (2013)

OTHER CRITERIA FOR THE QUALITY OF DATA (FROM BERTI-EQUILLE (2007))

Interpretability

- availability of the supplementary information and metadata
- covers the underlying concepts

Unicity

- one physical observation is represented by a unique object in the Dataset
- no duplicates

Conformity to Norm

- use the standardized encoding (reals, strings, statistical variables)

Consistency

- duplicated informations have the same value

Pre-processing of Data

Before any analysis : check the Data

Question on the Quality

- Are there missing values ? almost yes
- How many sampling are missing ?
- Is there a bias for missing data or randomly spread ?
- Is the bias in the dataset sufficiently important to modify the analysis (estimators, tests,...) ?

Give potential explanations

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Identification of Data Problems

Model of the Dataset (types, semantic,...)

- Missing Data (none or partial value)
- Non relevant
- Duplicated

Give potential explanations

PRE-PROCESSING OF DATA (2)

Distributions of Data Problems

Analyse the position of missing values in the Dataset

- MCAR, Missing Completely at random (unpredictable missing)
- MAR, Missing at random (predictable values : model)
- MNAR, Non missing at random

PRE-PROCESSING OF DATA (2)

Distributions of Data Problems

Analyse the position of missing values in the Dataset

- MCAR, Missing Completely at random (unpredictable missing)
- MAR, Missing at random (predictable values : model)
- MNAR, Non missing at random

Processing Missing Data

- Do nothing
- Remove samples with missing values
- Weighted analysis
- Value imputation (central tendency, EM, regression, random hot deck, neighbouring,...)

Report the method that has been used

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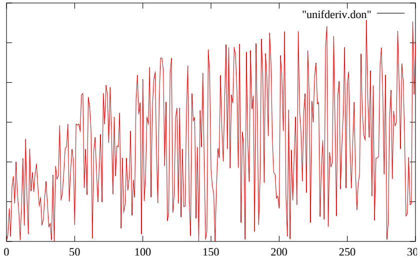
Analysis of Dataset (1)



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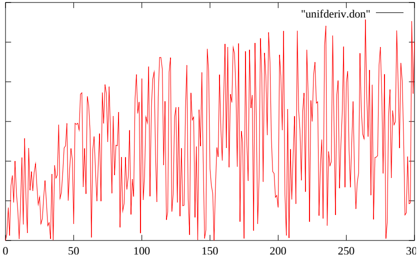
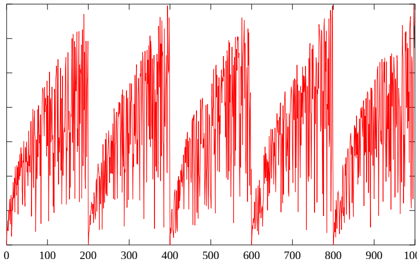


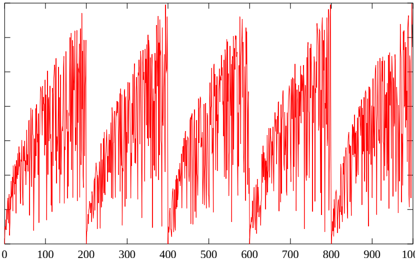
Tendency analysis

non homogeneous experiment
⇒ model the evolution of experiment
estimate and compensate tendency
explain why

Analysis of Dataset (2)



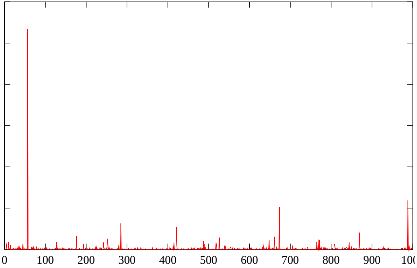
ANALYSIS OF DATASET (2)



Periodicity analysis

periodic evolution of the experimental environment ?
⇒ model the evolution of experiment
Fourier analysis of the sample
Integration on time (sliding window analysis) Danger : size of the window
Wavelet analysis
explain why

ANALYSIS OF DATASET (3)



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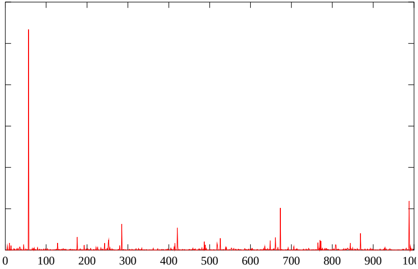
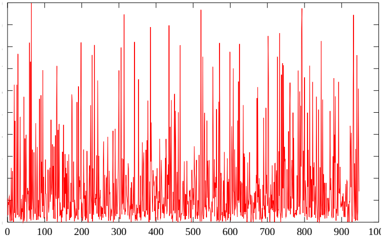


Non significant values

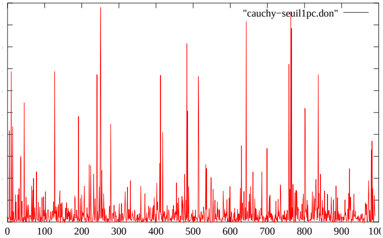
extraordinary behaviour of experimental environment
rare events with different orders of magnitude
⇒ threshold by value
Danger : choice of the threshold : indicate the rejection rate
⇒ threshold by quantile
Danger : choice of the percentage : indicate the rejection value
explain why

Analysis of Dataset (4)

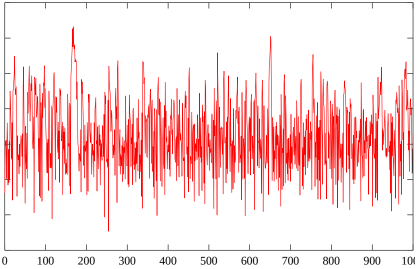
Threshold value : 10



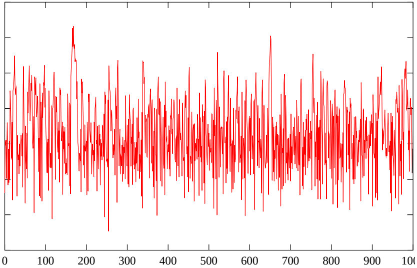
Threshold percentage : 1%



ANALYSIS OF DATASET (5)



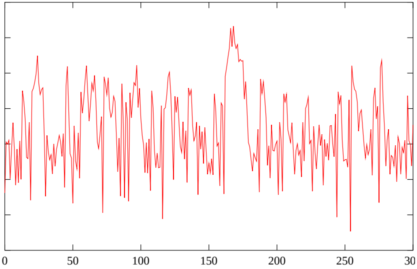
ANALYSIS OF DATASET (5)



looks like correct experiments
Statistically independent
Statistically homogeneous

Analysis of Dataset (5bis)

Zooming



ANALYSIS OF DATASET (5BIS)

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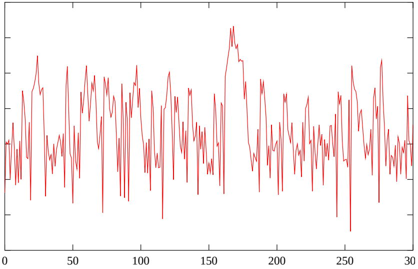


Autocorrelation

Danger time correlation among samples
experiments impact on experiments
⇒ stationarity analysis
autocorrelation estimation (ARMA)

EXPERIMENTAL RESULTS

After a campain of experiment/surveys

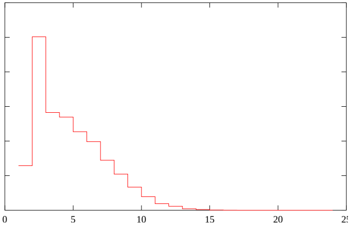
- Deterministic (controlled error non significant (white noise))
- Statistic (the system is non deterministic)

Sample analysis

- Identification of the response set
- Structure of the response set (measure)

Distribution analysis

Summarize data in a **histogram**

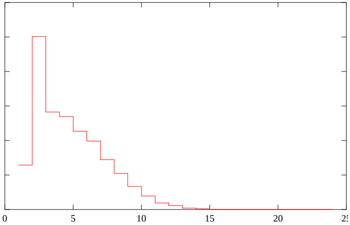


Shape analysis

- unimodal / multimodal
- variability
- symmetric / dissymmetric (skewness)
- flatness (kurtosis)

$\Longrightarrow$ **Central tendency analysis**
$\Longrightarrow$ **Variability analysis around the central tendency**

MODE VALUE



Mode

- **Categorical data**
- Most frequent value
- highly unstable value
- for continuous value distribution depends on the histogram step
- interpretation depends on the flatness of the histogram

$\Longrightarrow$ **Use it carefully**
$\Longrightarrow$ **Predictor function**

Median value

Median

- **Ordered data**
- Split the sample in two equal parts

$$\sum_{i \leqslant Median} f_i \leqslant \frac{1}{2} \leqslant \sum_{i \leqslant Median+1} f_i .$$

- more stable value
- does not depends on the histogram step
- difficult to combine (two samples)

$\Longrightarrow$ **Randomized algorithms**

MEAN VALUE

Mean

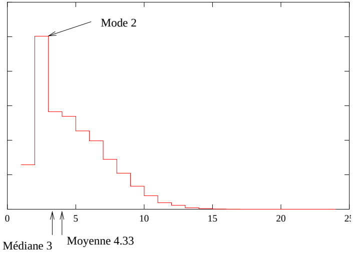
- Vector space
- Average of values

$$Mean = \frac{1}{Sample\_Size} \sum x_i = \sum_x x.f_x.$$

- stable value
- does not depends on the histogram step
- easy to combine (two samples $\Rightarrow$ weighted mean)

$\Longrightarrow$ **Additive problems (cost, durations, length,...)**

CENTRAL TENDENCY



Complementarity

- Valid if the sample is "Well-formed"
- **Semantic of the observation**
- Goal of analysis

$\Longrightarrow$ **Additive problems (cost, durations, length,...)**

CENTRAL TENDENCY (2)

Summary of Means

- Avoid means if possible
  Loses information
- Arithmetic mean
  When sum of raw values has physical meaning
  Use for summarizing times (not rates)
- Harmonic mean
  Use for summarizing rates (not times)
- Geometric mean
  Not useful when time is best measure of perf
  Useful when multiplicative effects are in play

VARIABILITY

Categorical data (finite set)

f_i : empirical frequency of element i
Empirical entropy

$$H(f) = \sum_i f_i \log f_i.$$

Measure the empirical distance with the uniform distribution

- $H(f) \geqslant 0$
- $H(f) = 0$ iff the observations are reduced to a unique value
- $H(f)$ is maximal for the uniform distribution

VARIABILITY (2)

Ordered data

Quantiles : quartiles, deciles, etc
Sort the sample :

$$(x_1, x_2, \cdots, x_n) \longrightarrow (x_{(1)}, x_{(2)}, \cdots, x_{(n)});$$

$$Q_1 = x_{(n/4)};\ Q_2 = x_{(n/2)} = Median;\ Q_3 = x_{(3n/4)}.$$

For deciles

$$d_i = argmax_i\{\sum_{j \leqslant i} f_j \leqslant \frac{i}{10}\}.$$

Utilization as quantile/quantile plots to compare distributions

VARIABILITY (3)

Vectorial data

Quadratic error for the mean

$$Var(X) = \frac{1}{n}\sum_{1}^{n}(x_i - \bar{x}_n)^2.$$

Properties :

$$\begin{aligned} Var(X) &\geqslant 0; \\ Var(X) &= \overline{x^2} - (\bar{x})^2, \text{ où } \overline{x^2} = \frac{1}{n}\sum_{i=1}^{n} x_i^2. \\ Var(X + cste) &= Var(X); \\ Var(\lambda X) &= \lambda^2 Var(X). \end{aligned}$$

Pre-processing of Data (3)

Variability Model of Data

Analyse the variability of the variables
Establish an hypothesis for the variability

- Deterministic properties
- Gaussian noise (parametric approach)
- Quantiles (non-parametric approach)

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Analysis of Outliers

Assumption : the outliers of the observed phenomena are not frequent

- Do nothing
- Remove outliers
- Weighted analysis
- Value imputation (central tendency, EM, regression, random hot deck, neighbouring,...)

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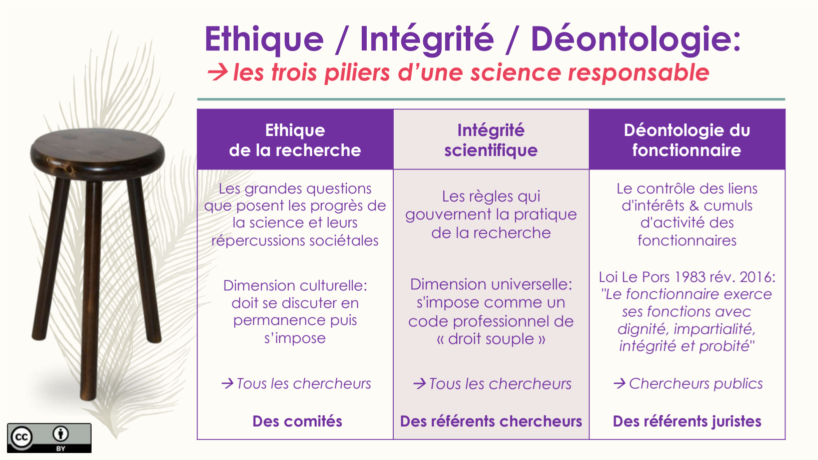
TO GO FURTHER



Ethique / Intégrité / Déontologie:

→ *les trois piliers d'une science responsable*

Ethique de la recherche	Intégrité scientifique	Déontologie du fonctionnaire
Les grandes questions que posent les progrès de la science et leurs répercussions sociétales	Les règles qui gouvernent la pratique de la recherche	Le contrôle des liens d'intérêts & cumuls d'activité des fonctionnaires
Dimension culturelle: doit se discuter en permanence puis s'impose	Dimension universelle: s'impose comme un code professionnel de « droit souple »	Loi Le Pors 1983 rév. 2016: *"Le fonctionnaire exerce ses fonctions avec dignité, impartialité, intégrité et probité"*
→ *Tous les chercheurs*	→ *Tous les chercheurs*	→ *Chercheurs publics*
Des comités	**Des référents chercheurs**	**Des référents juristes**

by Olivier Le Gall Inra Bordeaux

References

Promouvoir une recherche intègre et responsable

Un guide

Comité d'éthique du CNRS
www.cnrs.fr/comets
juillet 2014

Vers une recherche reproductible

Faire évoluer ses pratiques

Loïc Desquilbet, Sabrina Granger, Boris Hejblum,
Arnaud Legrand, Pascal Pernot, Nicolas Rougier