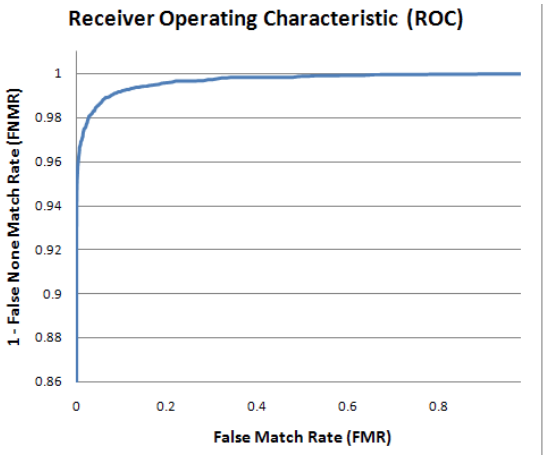
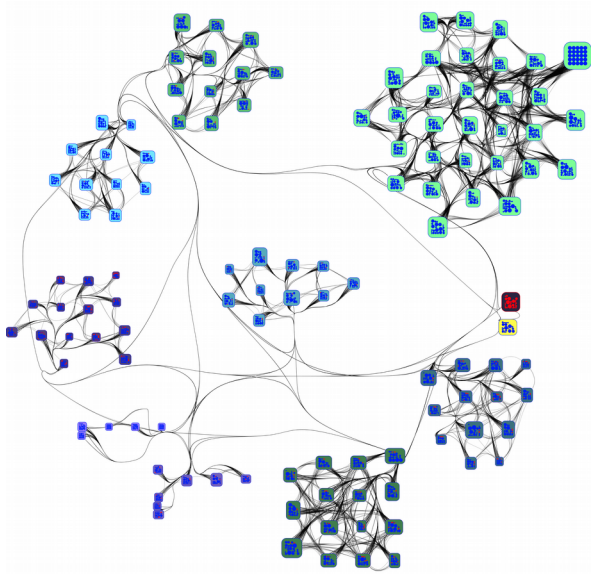
Visualization for Biometric Evaluation





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Introduction

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Who am I ?

- Work place
  - University of Bordeaux
    - IUT Bordeaux
    - Computer Science department
  - Laboratoire Bordelais de Recherche en Informatique
- Research works
  - Biometric authentication
    - Keystroke dynamics, multibiometrics, template update
  - Large graph visualization
    - Node placement, edge routing

Visualization for biometric evaluation - plan

- Few information about data visualization
- Quick introduction to biometric authentication
- Presentation of
  - Common visual tools used to evaluate biometric authentication systems
  - Novel one which focus on other aspects

Some principles of visualisation (with few information on perception)

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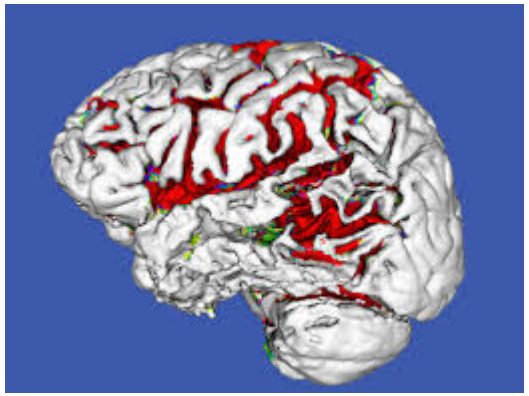
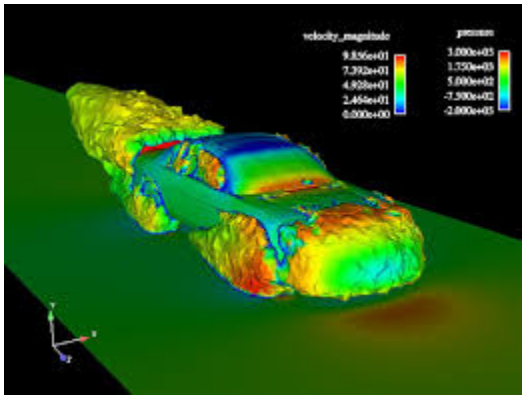
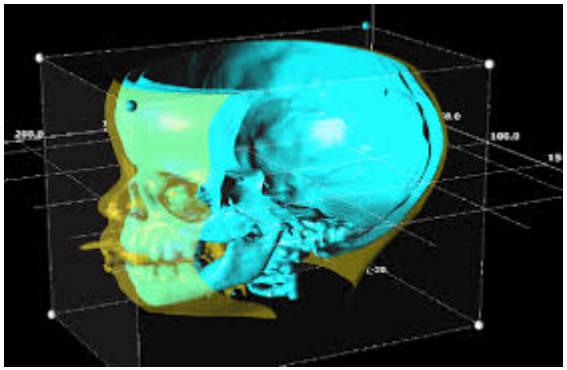
Data visualization

- « The use of computer-supported, interactive, visual representations of data to amplify cognition » [Card 99]
- Scientific visualization

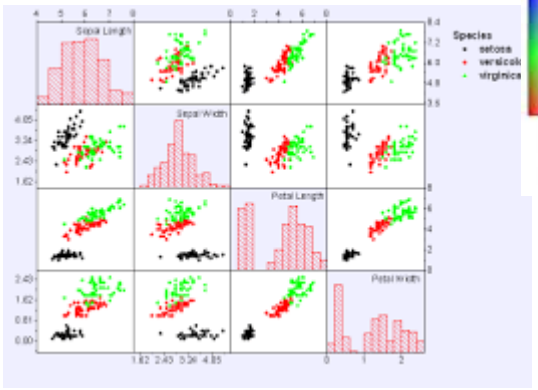


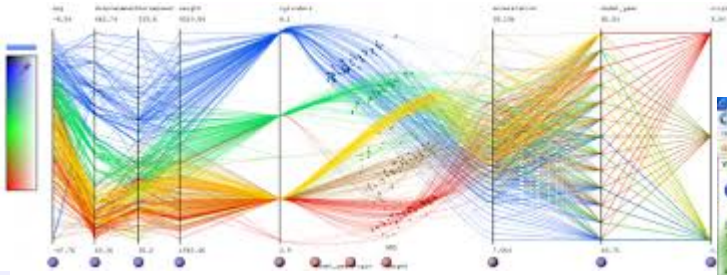


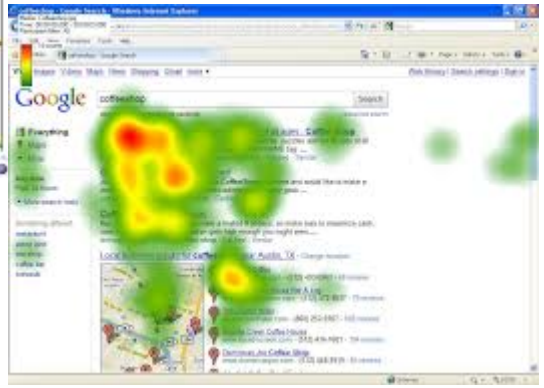


Data visualization

- « The use of computer-supported, interactive, visual representations of data to amplify cognition » [Card 99]
- Information visualization

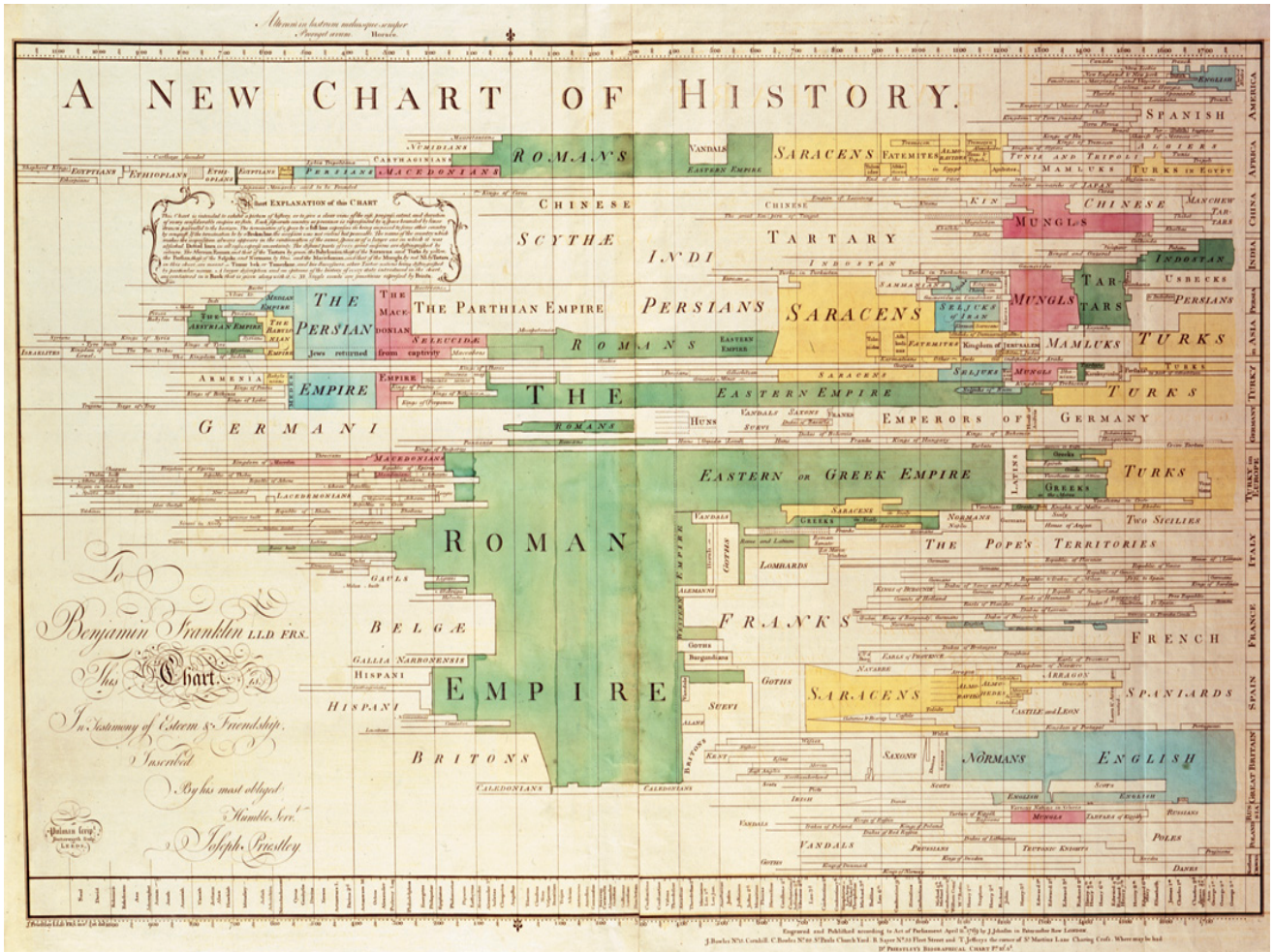






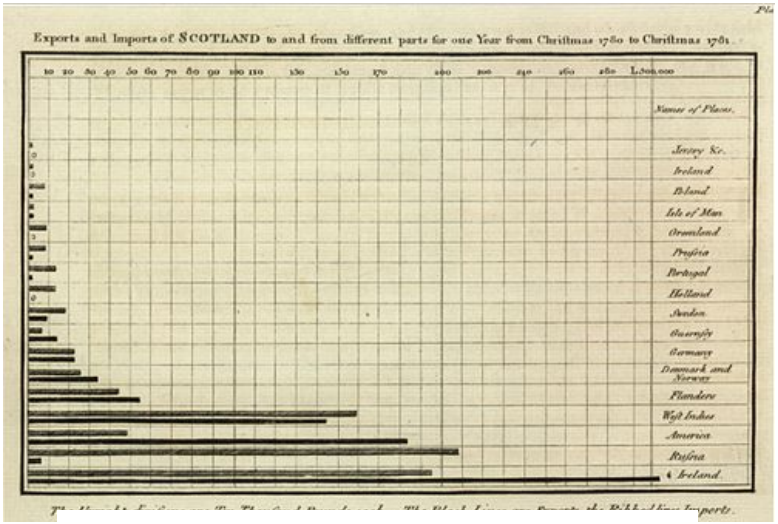
Data visualization pionners
Joseph Priestley 1733-1804

- Discover of Oxygen, inventor of timeline charts (1769)

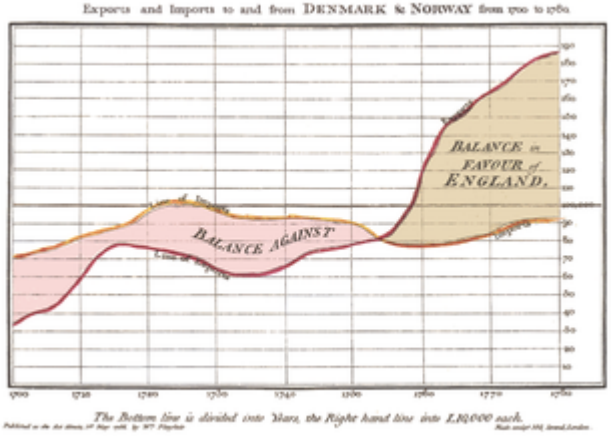


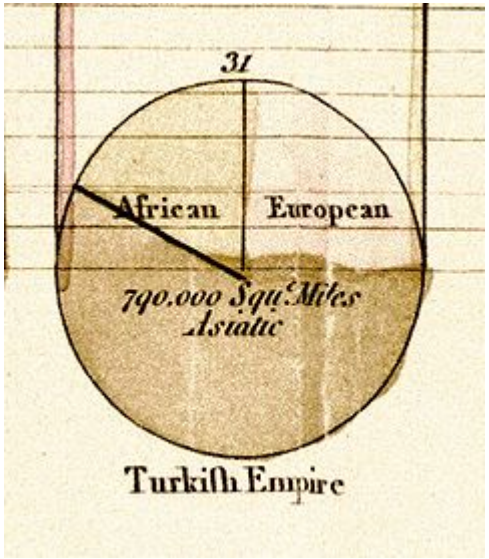
Data visualization pionners
William Playfair 1759-1823

- Founder of graphical methods of statistics : line, bar, area, and pie charts.



1786

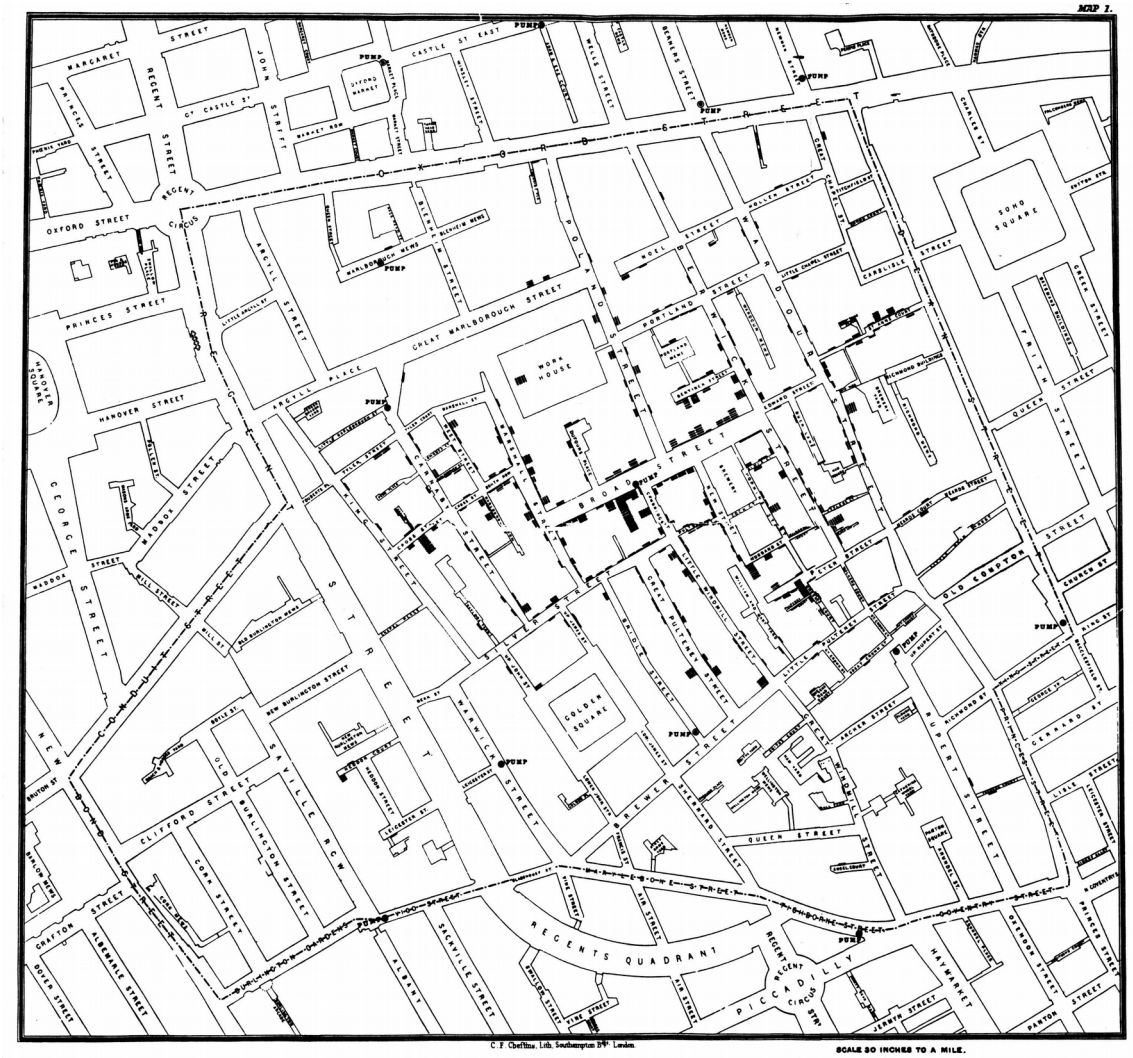




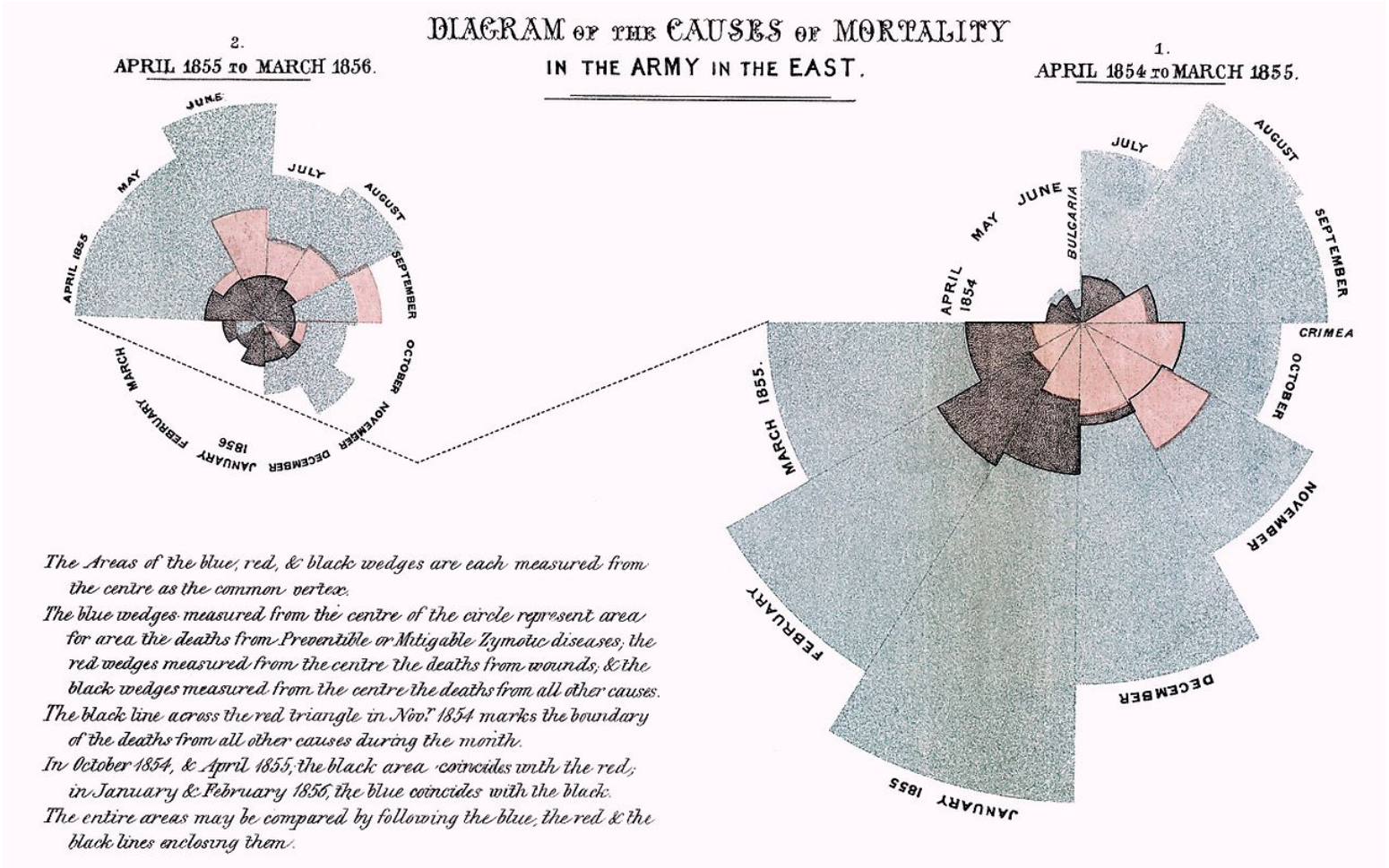
1801

Data visualization pionners
John Snow 1813 -1858

- 1854 Broad Street cholera outbreak

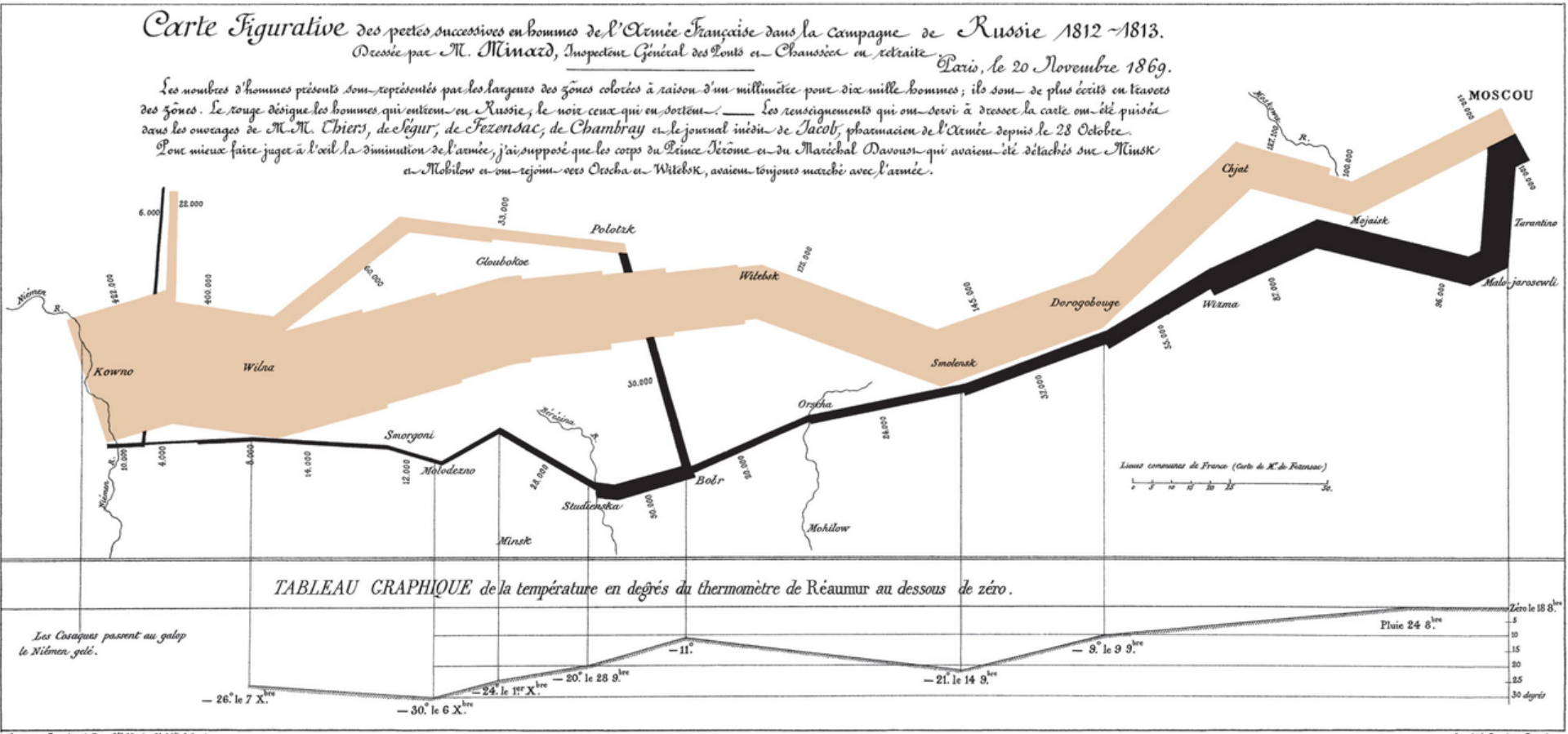


Data visualization pionners
Florence Nightingale 1820-1910

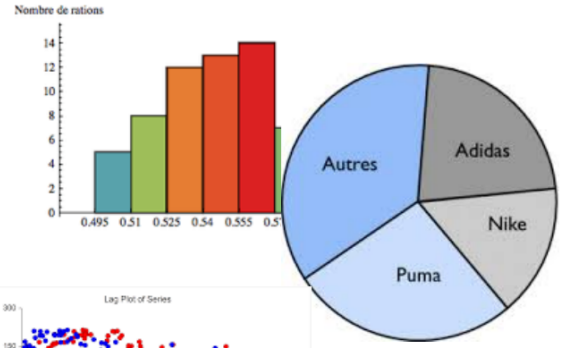


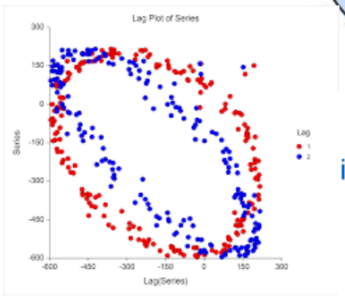
Data visualization pionners
Joseph Minard 1781-1870

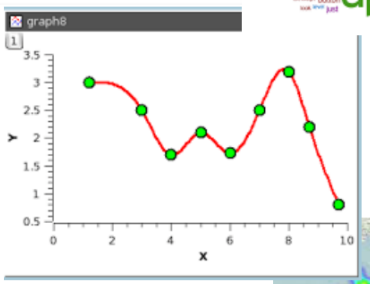
- Sankey diagrams (1869)

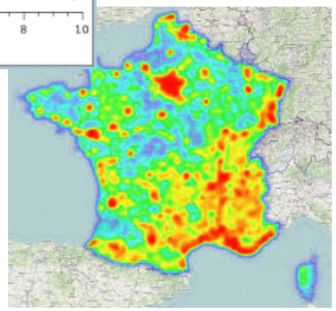


Since then, more visualization methods have been used









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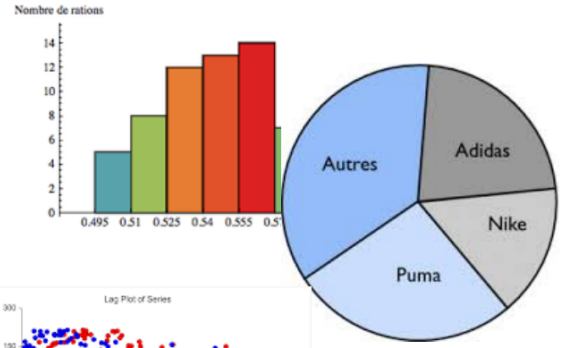

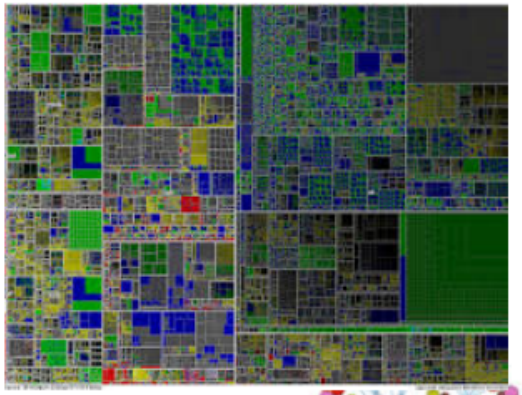

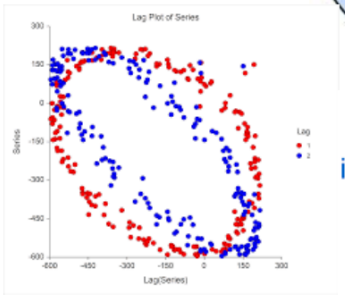

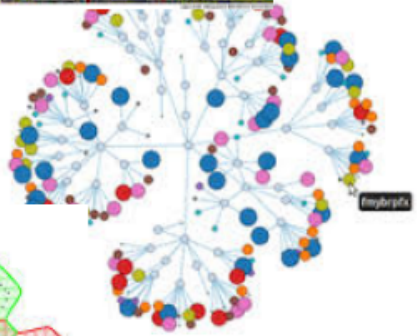

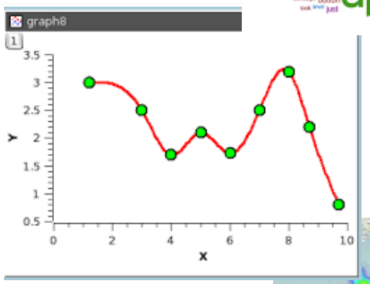

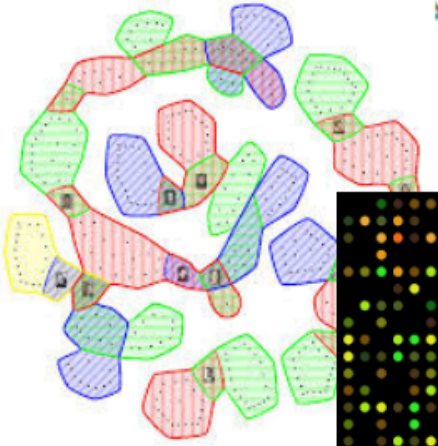

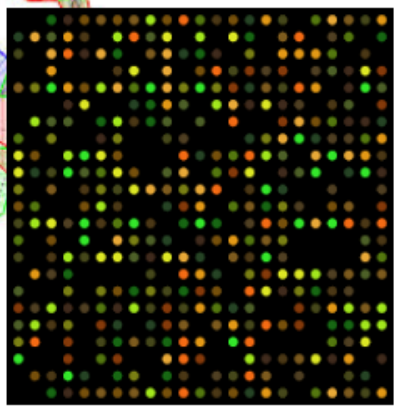

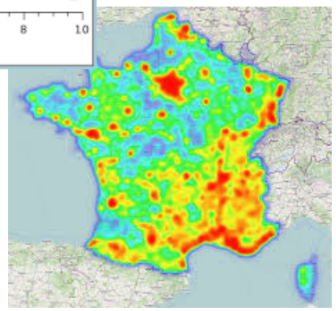

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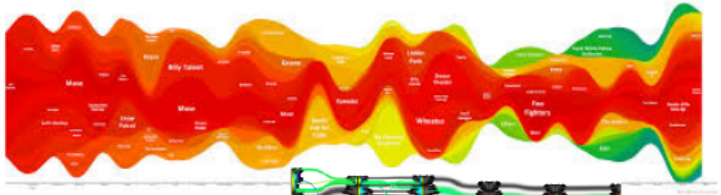
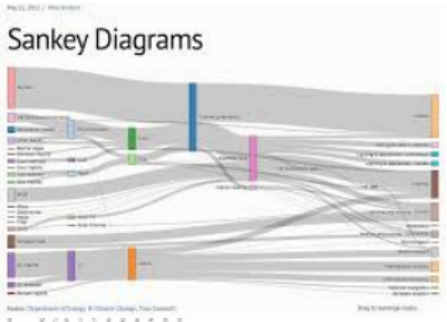
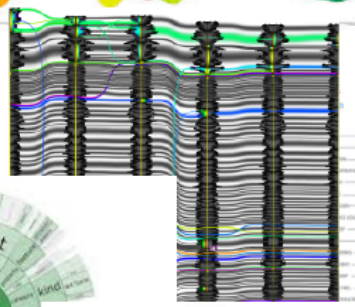
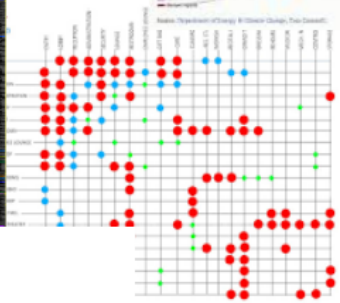
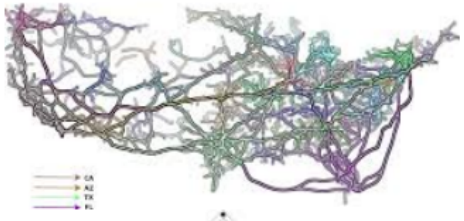
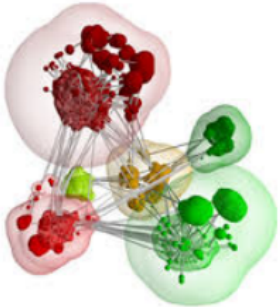


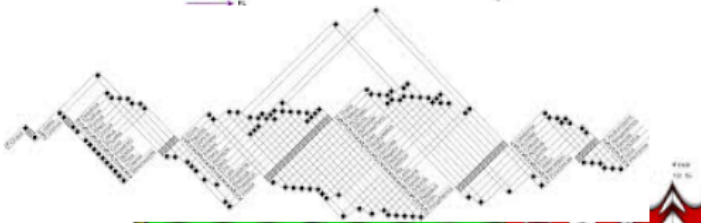


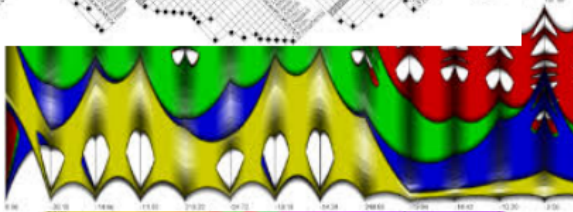


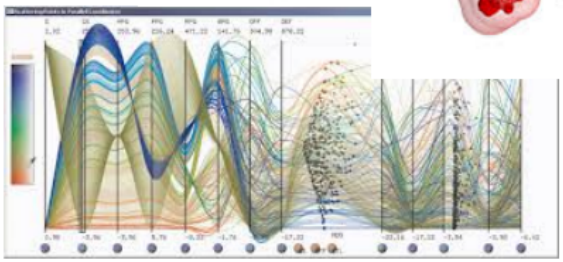


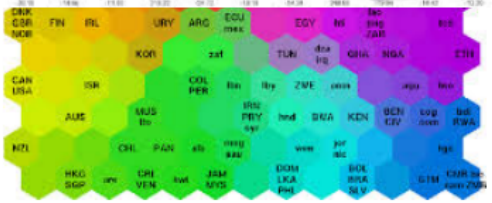






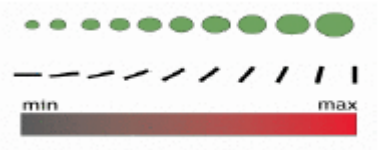






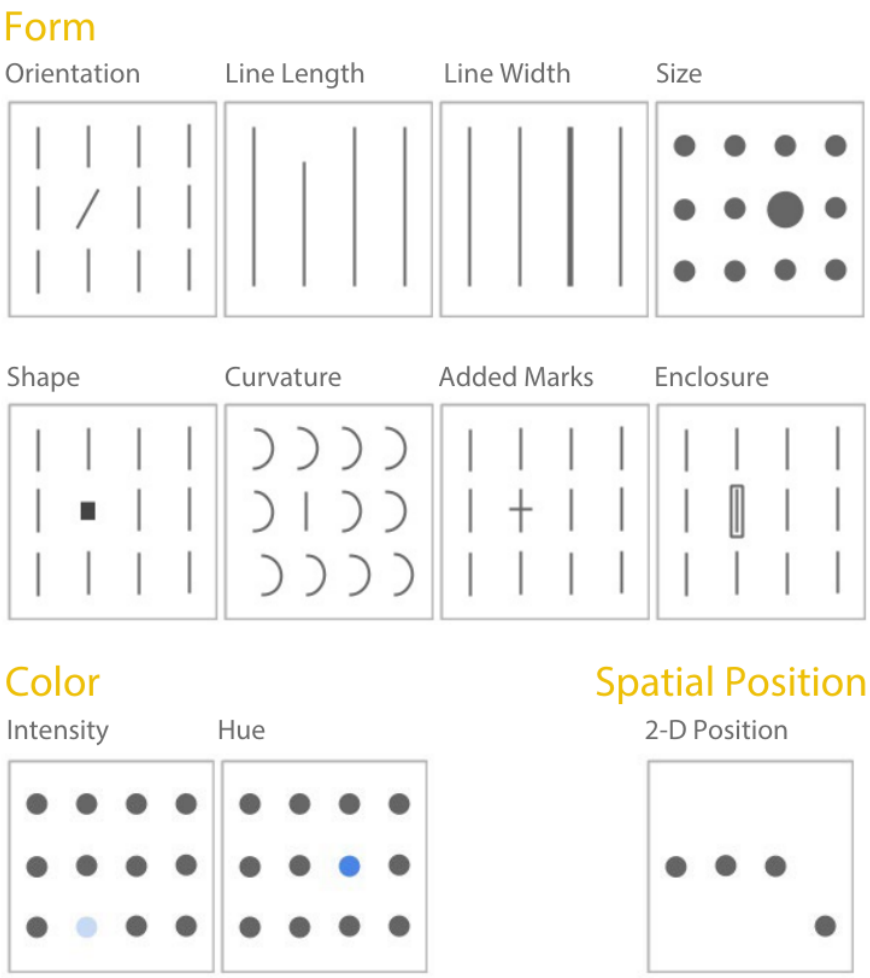
What is a data ?

- Fundamental types of data
  - Entities
  - Relations (between entities)
- Attributes
  - Quantitative
    - Number of inhabitants, area, ...
  - Ordinal
    - Result of a competition
  - Categorical/Nominal
    - Brand of a car



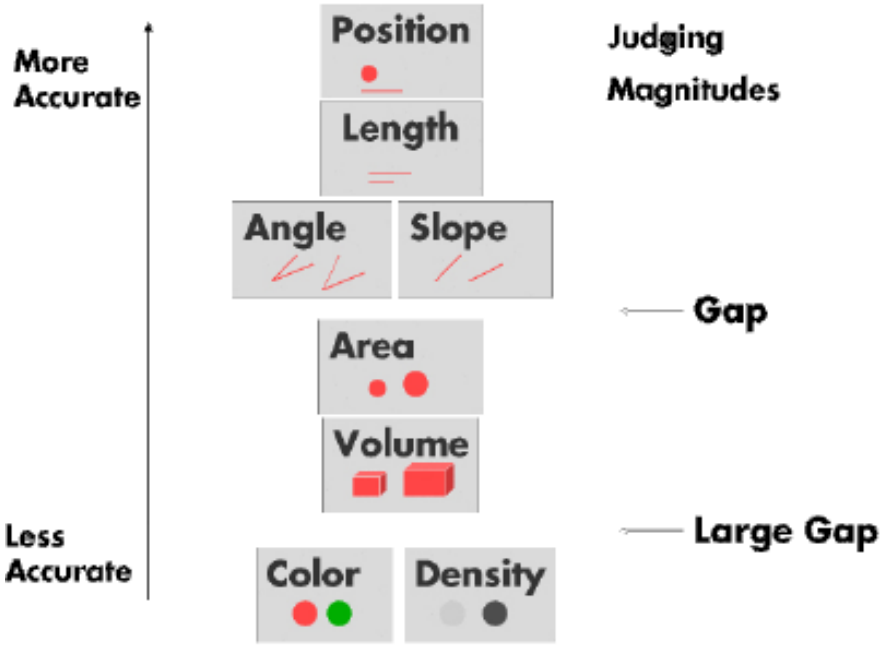
Several visual attributes exist

- Position
- Density
- Shape
- Size
- Texture
- Orientation
- Saturation
- Curvature
- Movement
- Text
- …



http://www.fusioncharts.com/

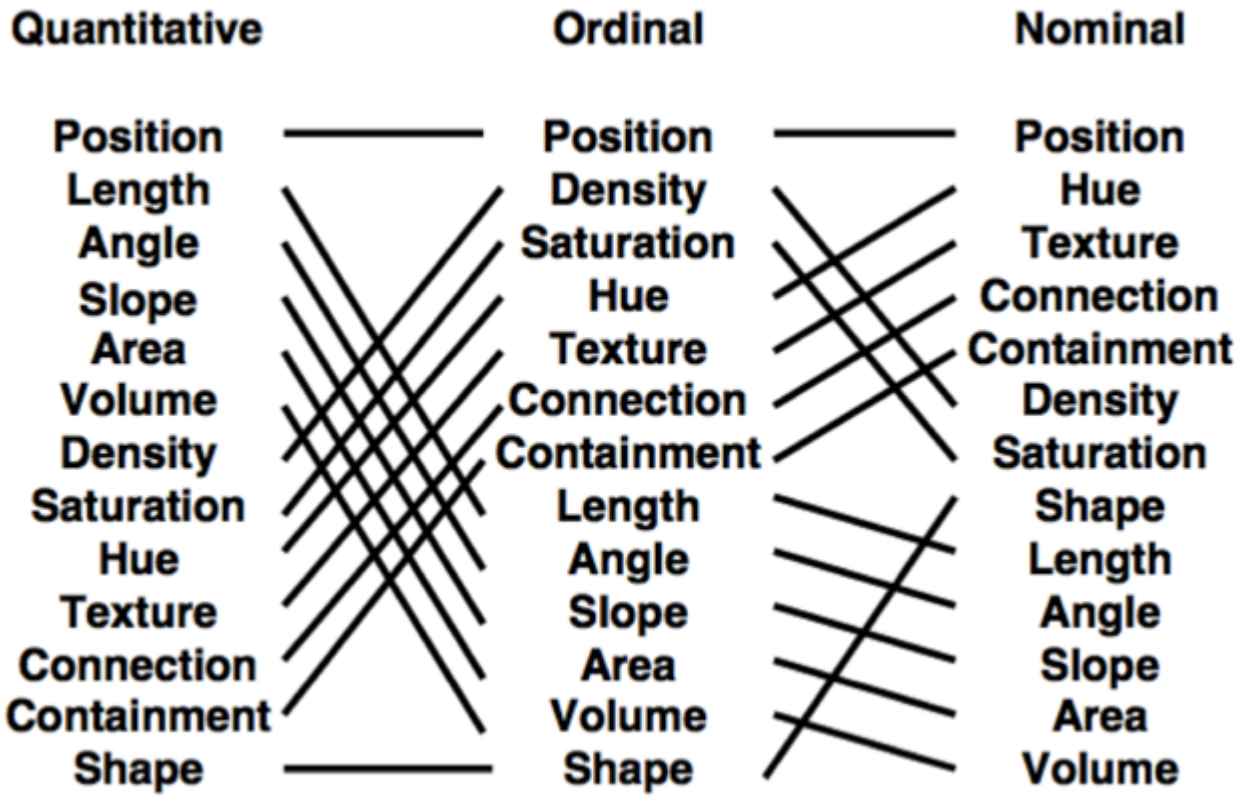
Visual attributes – quantitative attributes



- Often used but bad
  - Color & density
- More accurate
  - Position, length, orientation

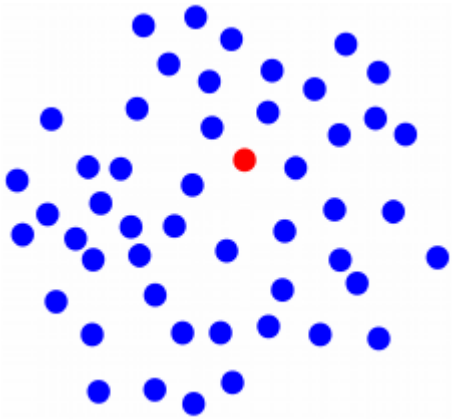
[Mackinley]

Visual attributes – choice order



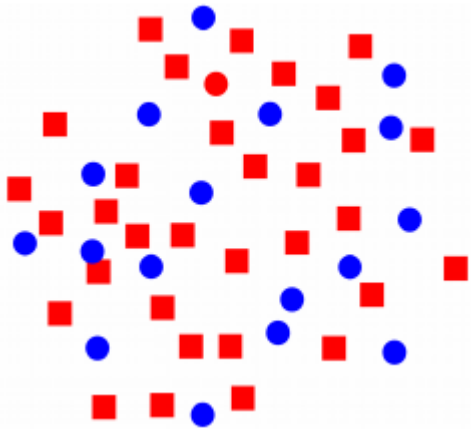
[Mackinley]

Interpretation can be complex – cognitive load



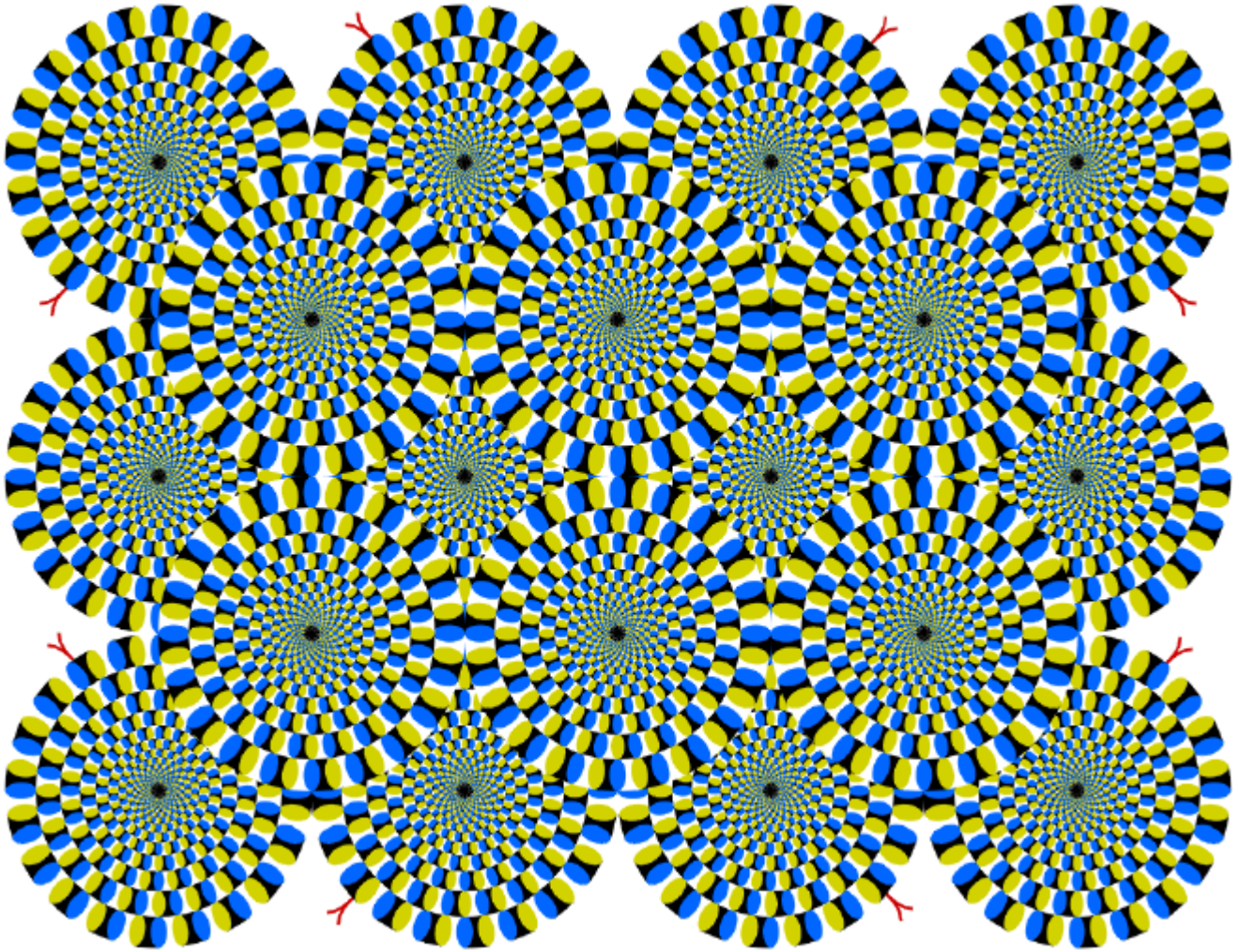
low

medium



high

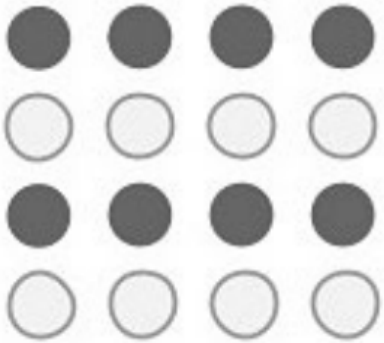
Interpretation can be erroneous



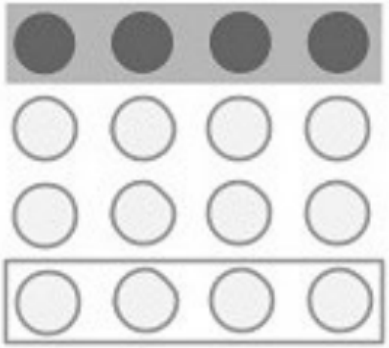
Gestalt law – Relations representation

Proximity

Similarity



Enclosure



Symmetry

Closure

Continuity

Connection

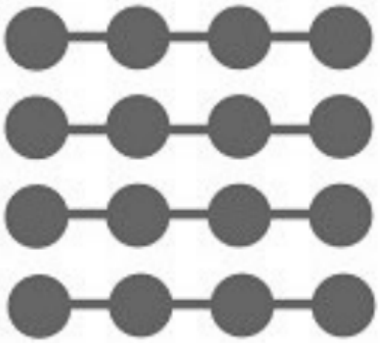
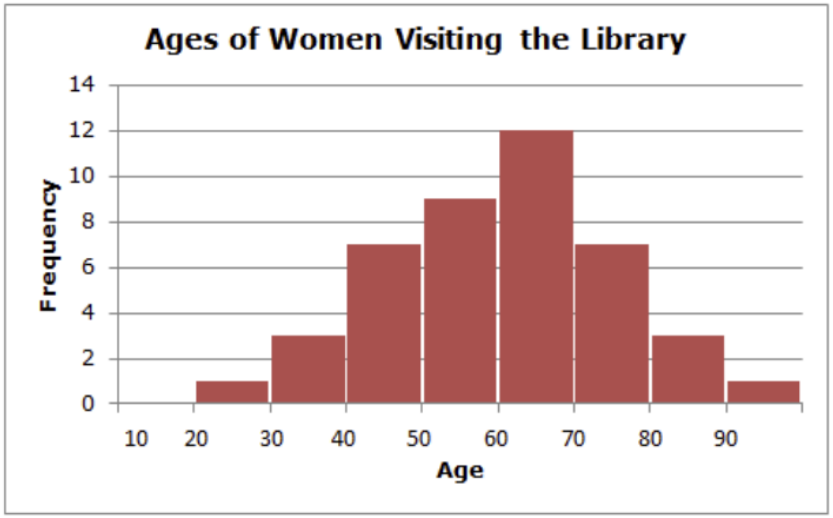
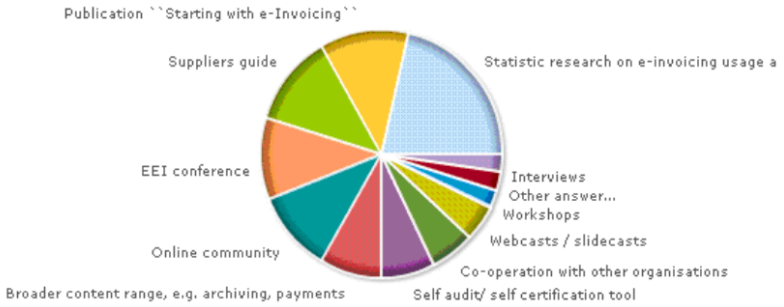


Figure & ground

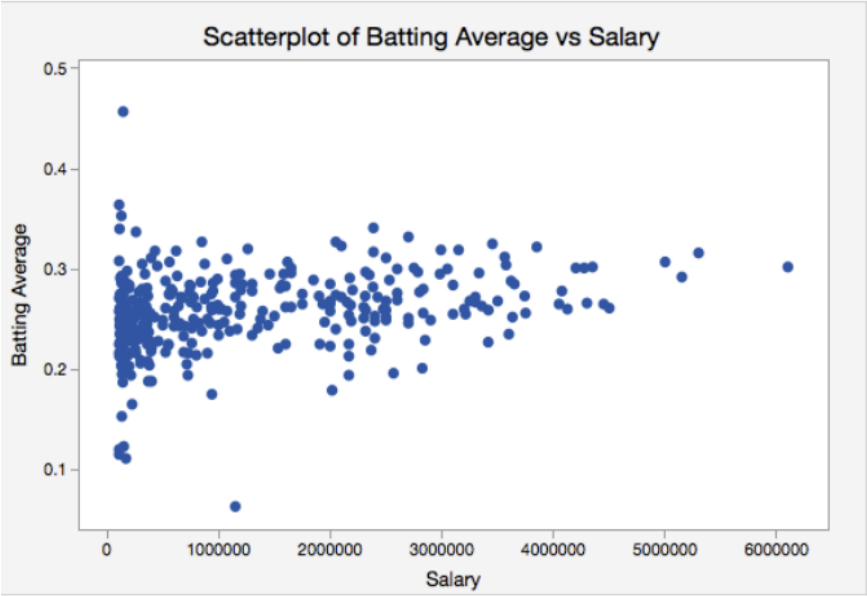
http://www.fusioncharts.com/

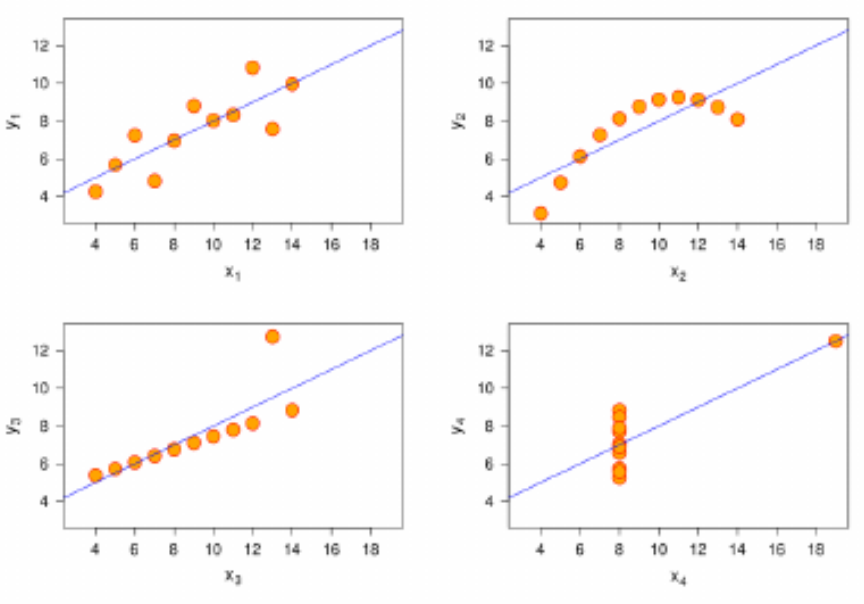
One dimensional data visualization - examples





Two dimensional data visualization - examples

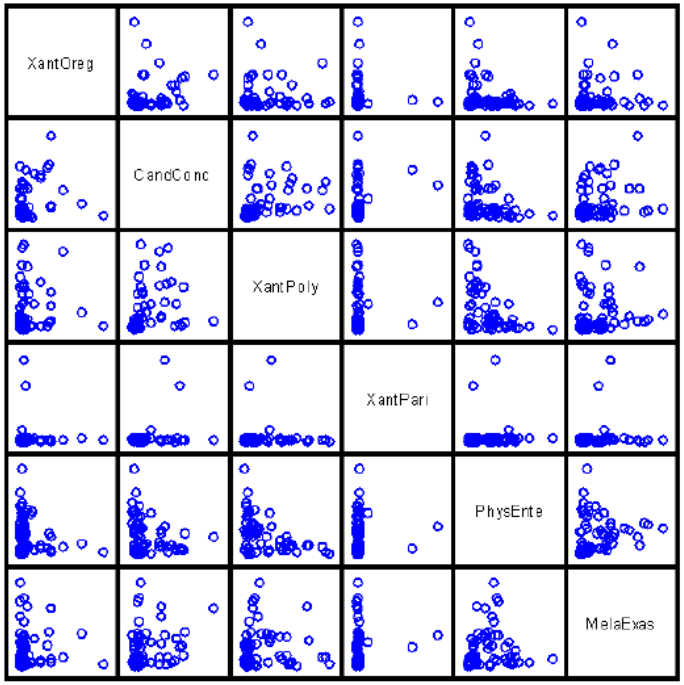


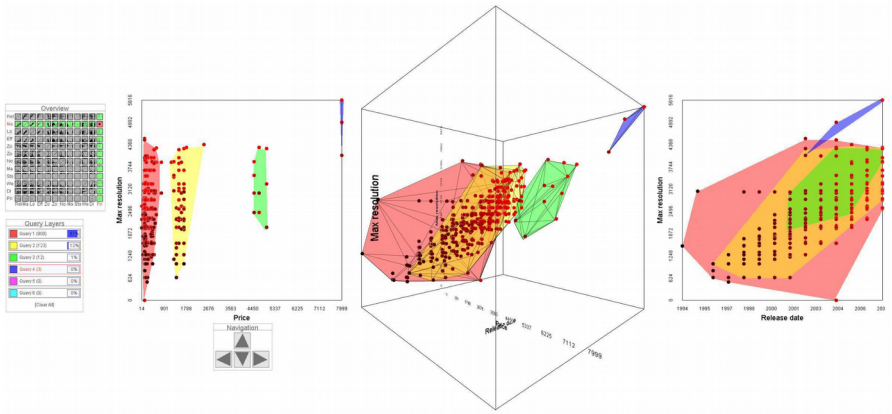


Anscombe's quartet

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

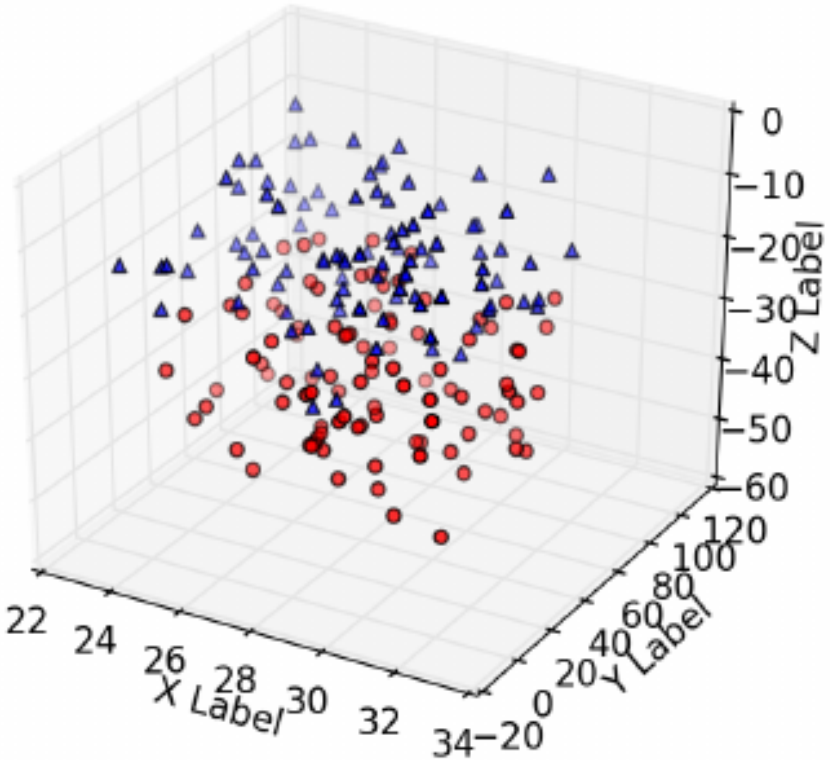
More than 2 dimensional data visualization - examples

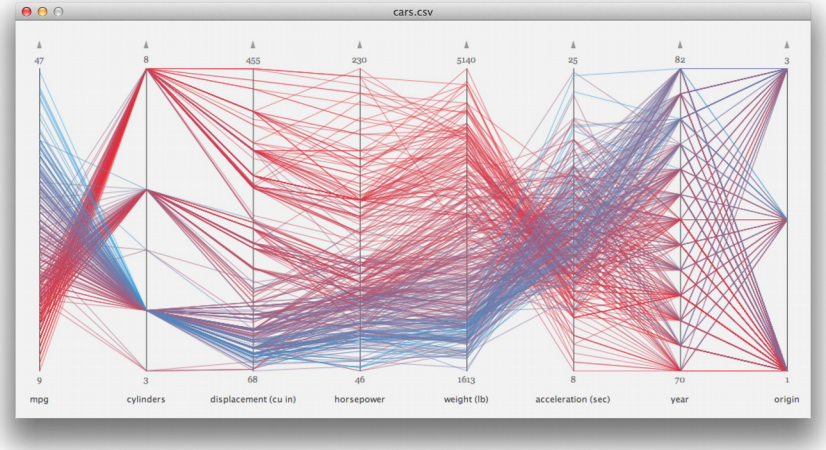


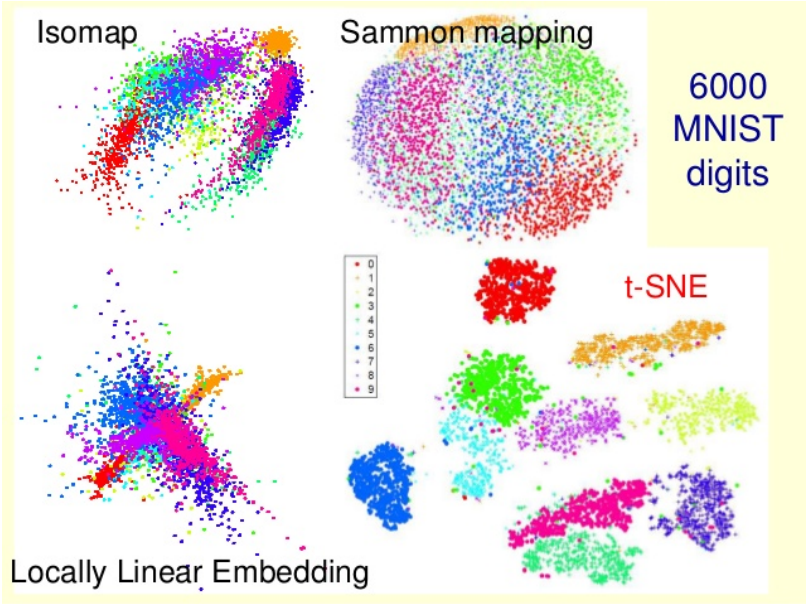


[Elmqvist2008]

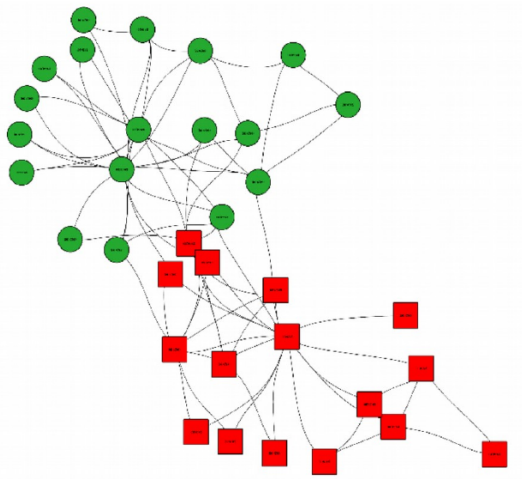
More than 2 dimensional data visualization - examples

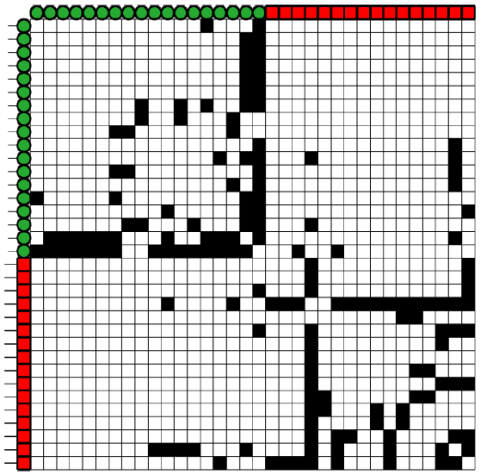


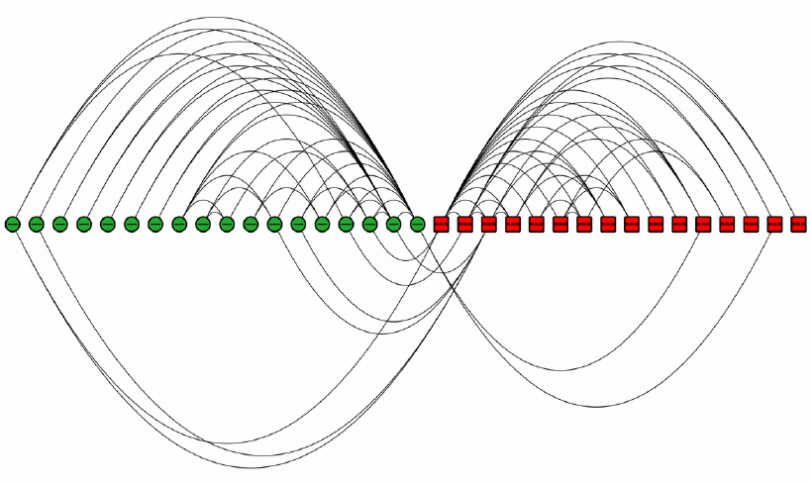




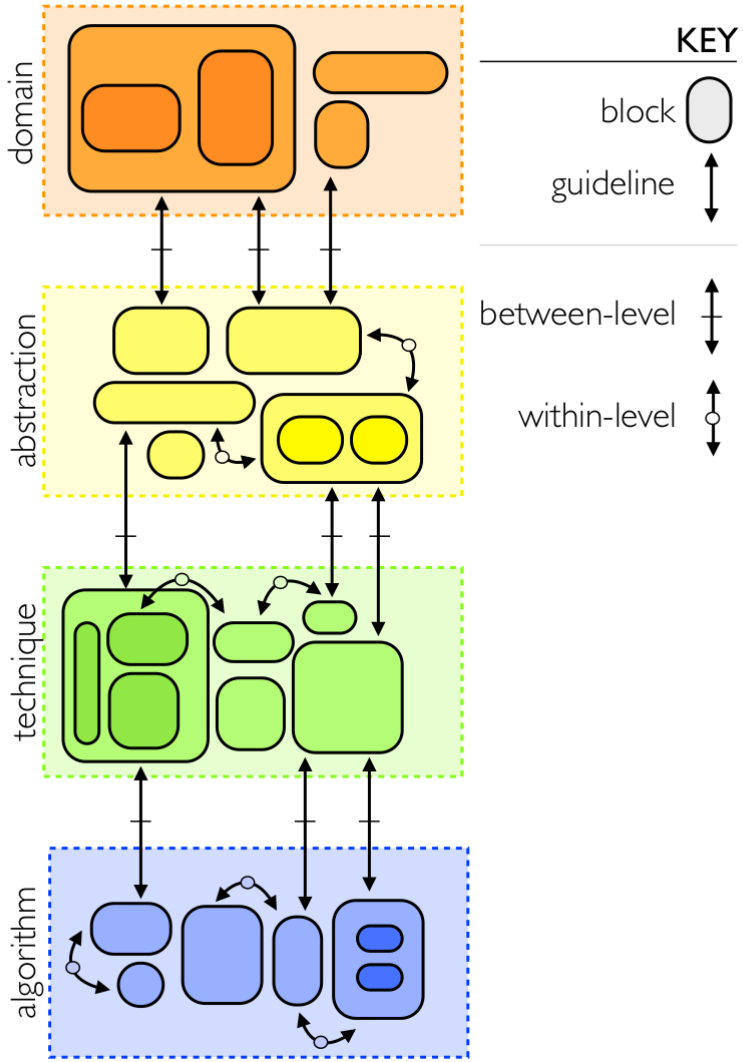
Visualization of relational data







The Nested Blocks and Guidelines Model



The Nested Blocks and Guidelines Model. Miriah Meyer, Michael Sedlmair, P. Samuel Quinan, and Tamara Munzner.Information Visualization 14(3), Special Issue on Visualization Evaluation (BELIV)

Very fast introduction to biometric authentication

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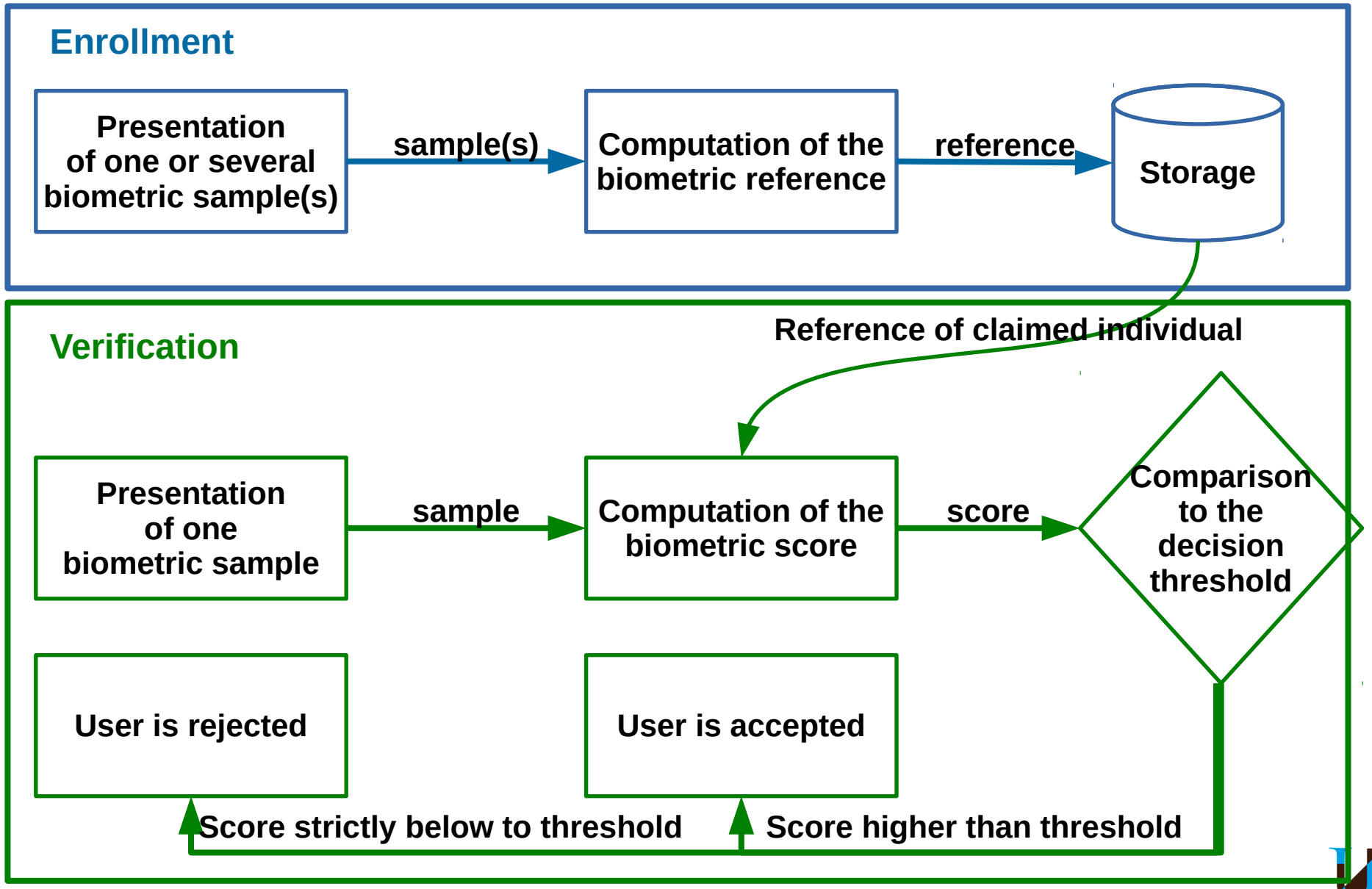
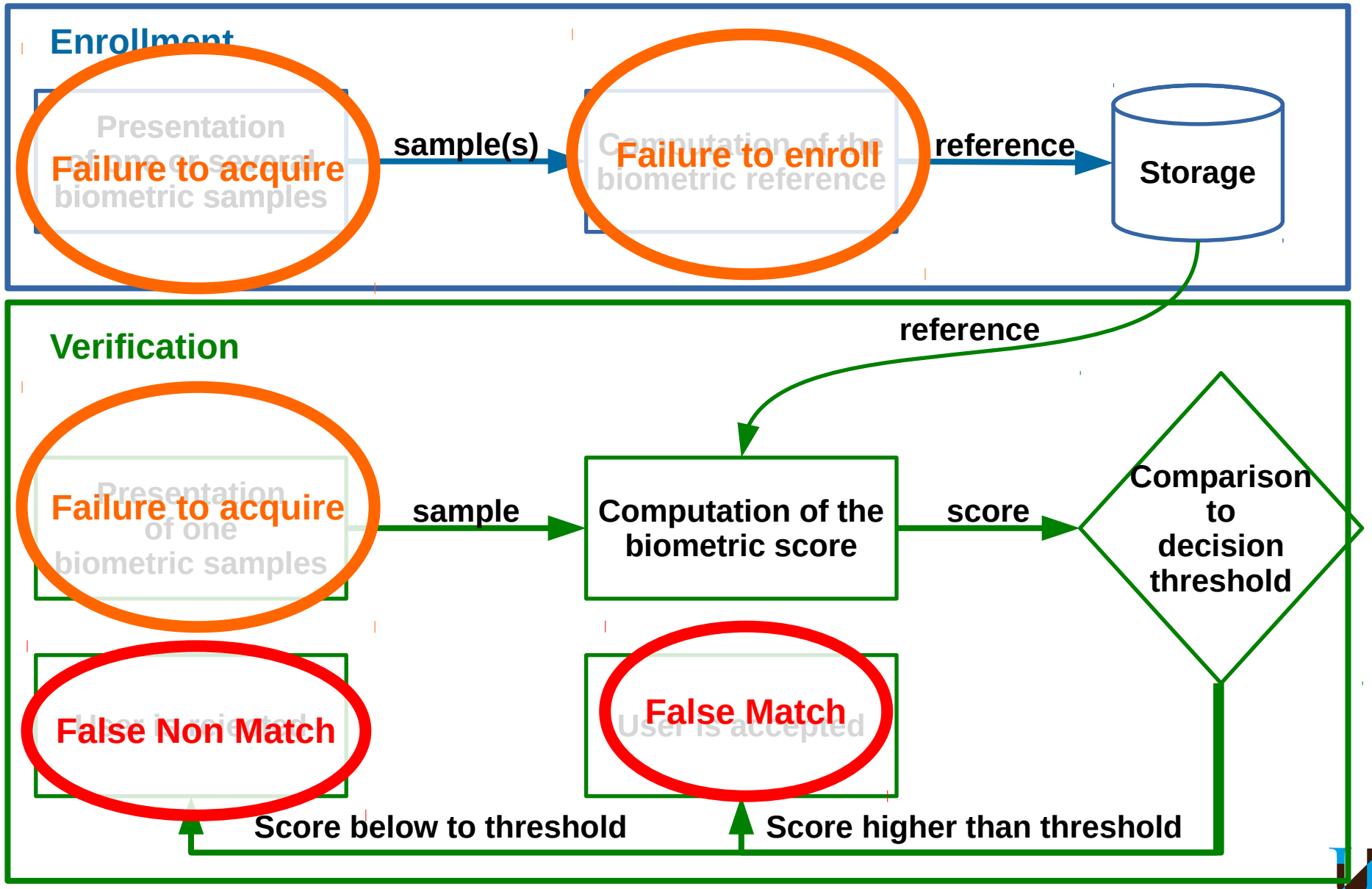
Biometric authentication

- Sole authentication based on what we are
  - Use of biometric data
  - Very hard to share (better than a password)
  - Vary hard to be stolen or lost (better than a token)
- Various modalities exist
  - Physiological: face recognition, iris recognition, voice recognition, ...
  - Behavioral: keystroke & mouse dynamics, voice recognition, signature,

Basic workflow of a biometric authentication system

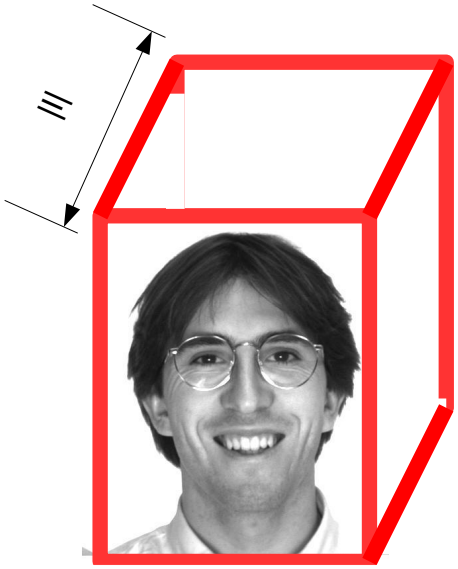


Basic workflow of a biometric authentication system



Score Database Generation

- Need of a database of samples
  - Gallery and Probe
- **Gallery serves to compute the biometric references**
- Use of the probe to compute biometric scores
  - Intrascores (|I|*|P|)
  - Interscores (|I|*|I|*|P|)
- Usual metrics
  - False Non Match Rate
  - False Match Rate
  - Equal Error Rate



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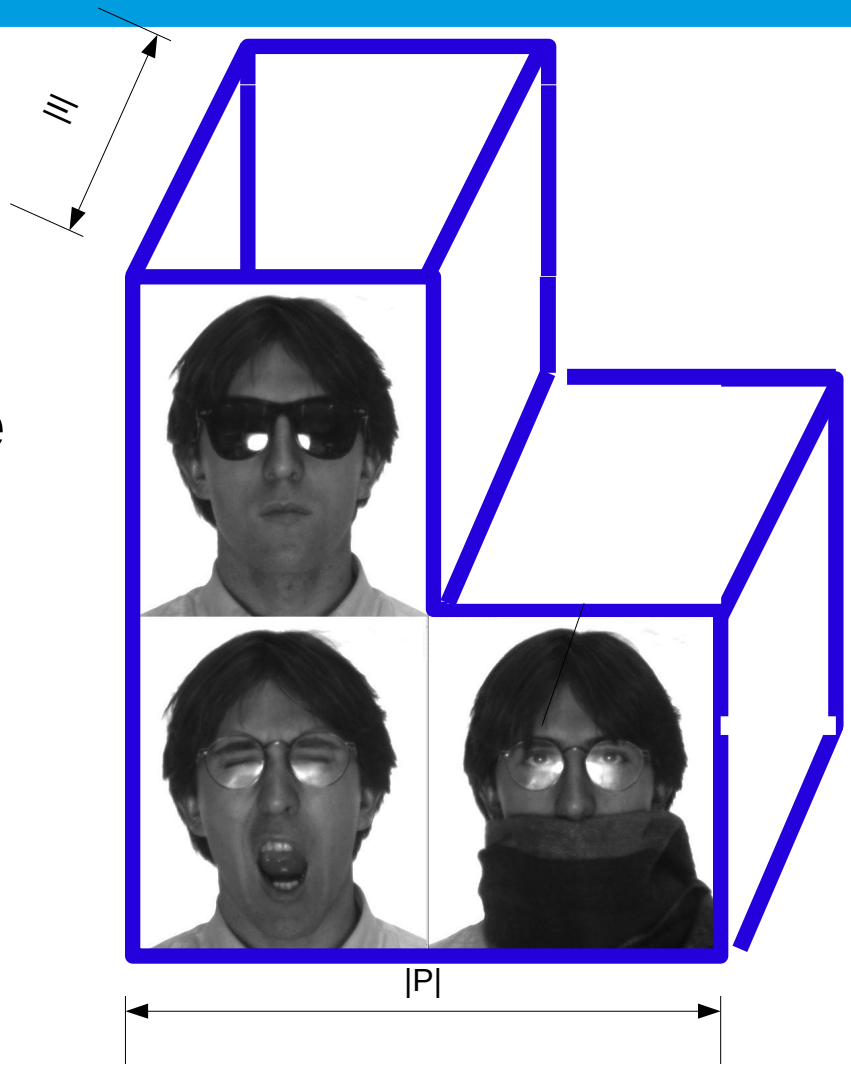
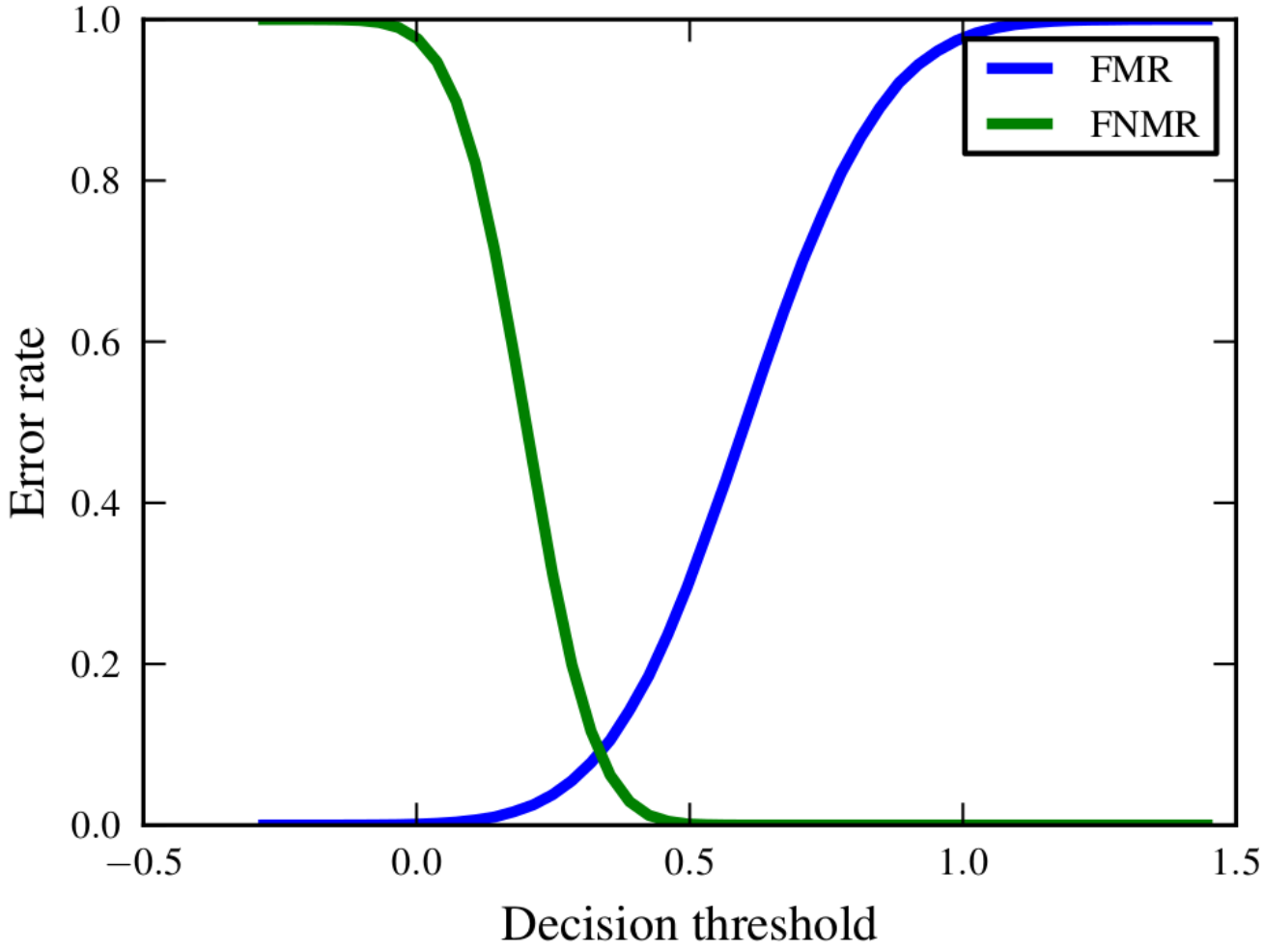


Score Database Generation

- Need of a database
  - Gallery and Probe
- Gallery serves to compute the biometric
- Use of the probe to compute biometric scores
  - Intrascores (|I|*|P|)
  - Interscores (|I|*|I|*|P|)
- Usual metrics
  - **False Non Match Rate**
  - **False Match Rate**
  - **Equal Error Rate**

	A	B	C	D
1	Gallery	Probe	Comparison	Score
2	1	1	1	58
3	1	1	2	75
4	1	1	3	25
5	1	1	4	22
6	1	1	5	40
7	1	1	6	18
8	1	1	7	37
9	1	1	8	18

The performance depends on the decision threshold



Standard visual evaluation tools for biometric authentication

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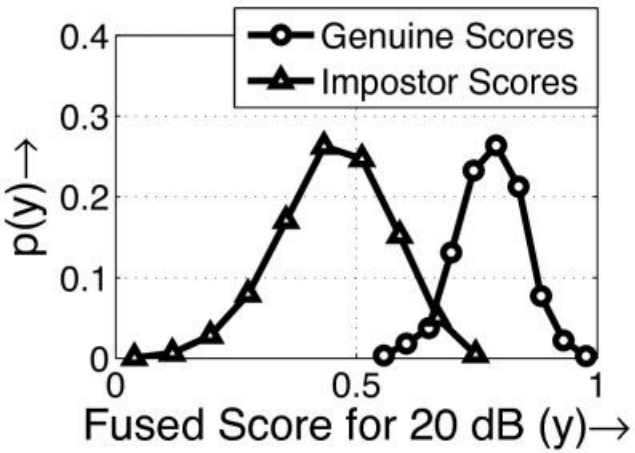
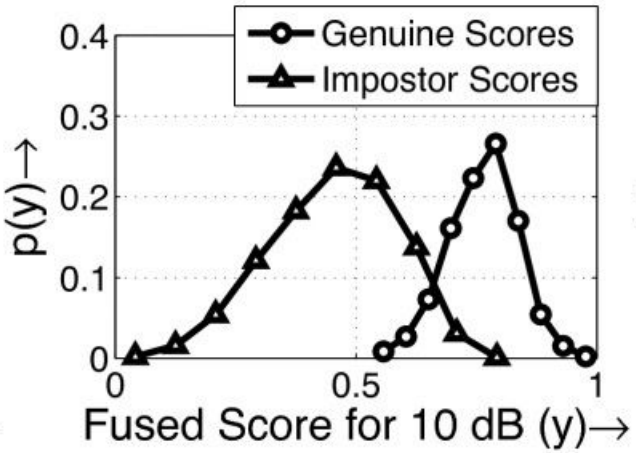
Biometrics Evaluation and Testing

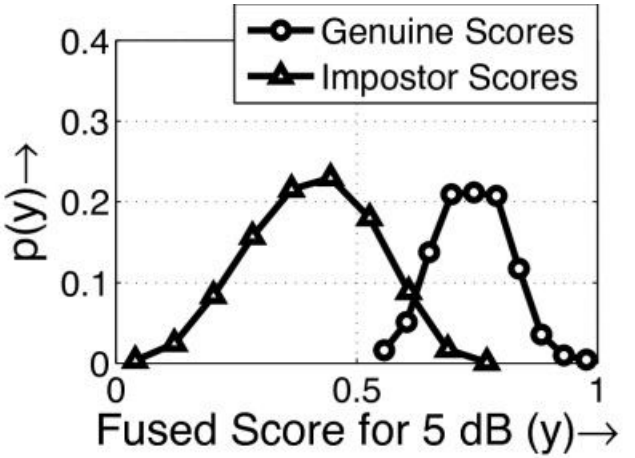
- BEAT project funded by the European Commission, under the Seventh Framework Program (2011-2017) lists
  - Receiver Operating Characteristic (ROC)
  - Detection Error Trade-off (DET)
  - Expected Performance Curve (EPC)
- Other visualizations
  - Scores distribution
  - Zoo plot

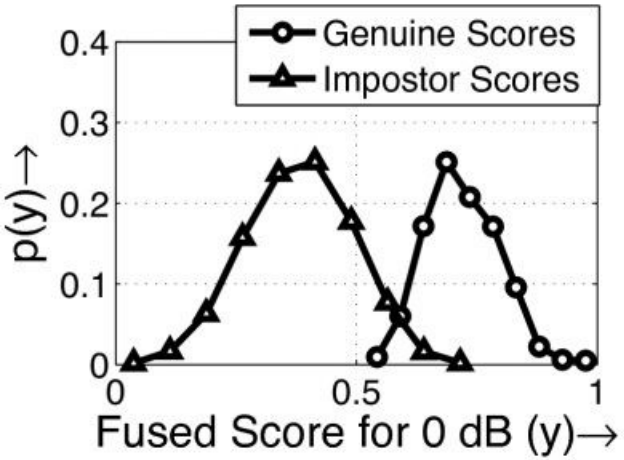
[Poh et al. 2012]

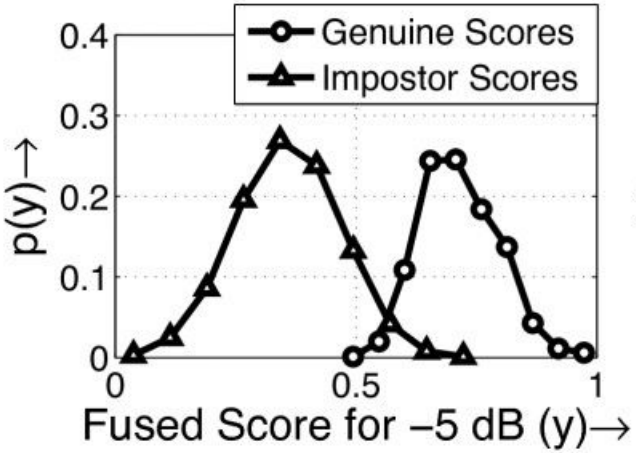
Scores distribution

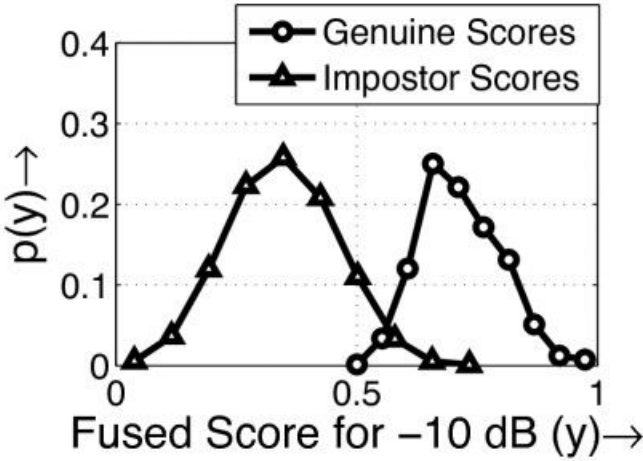






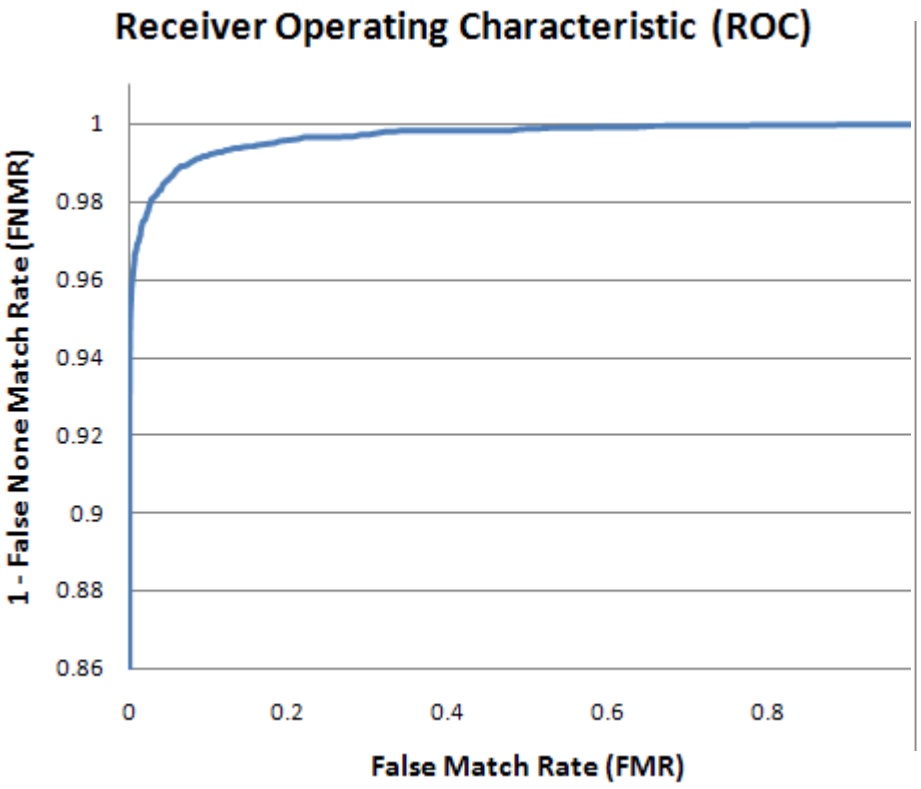


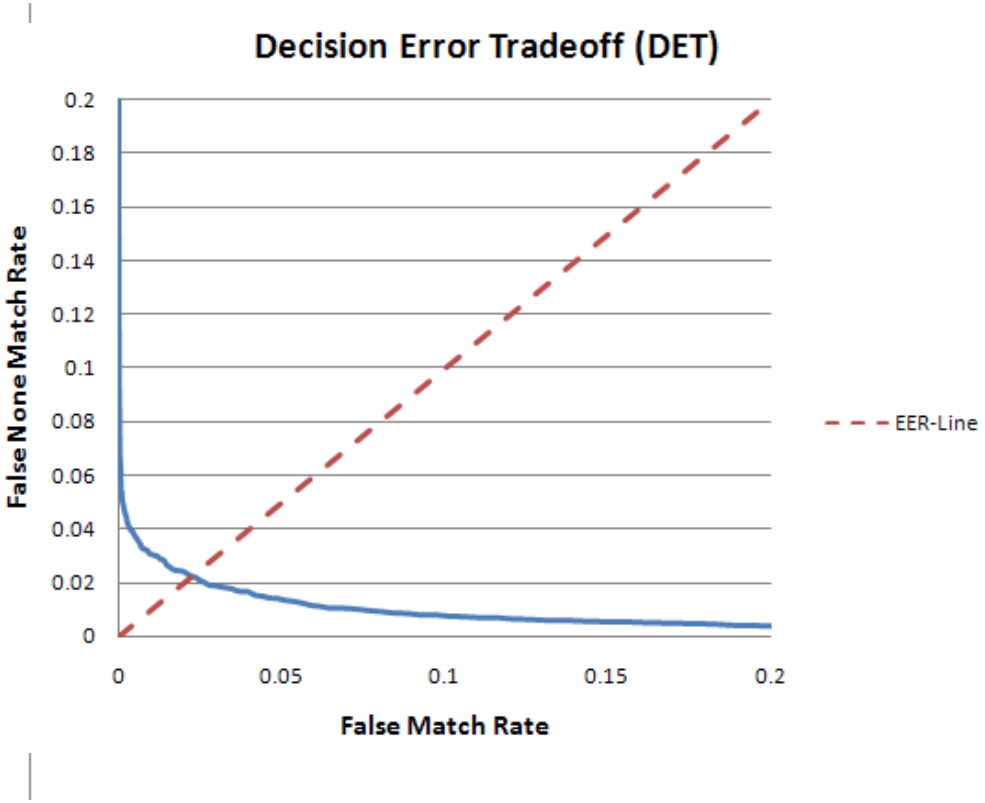




[Anzar et al. 2013]

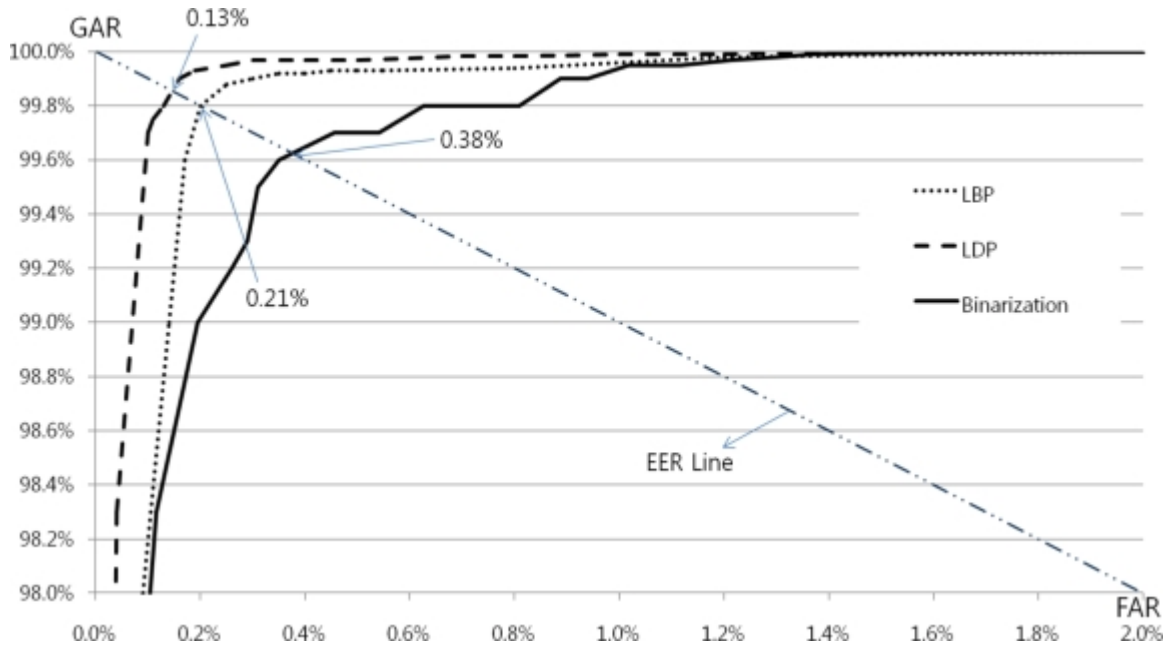
The ROC curve





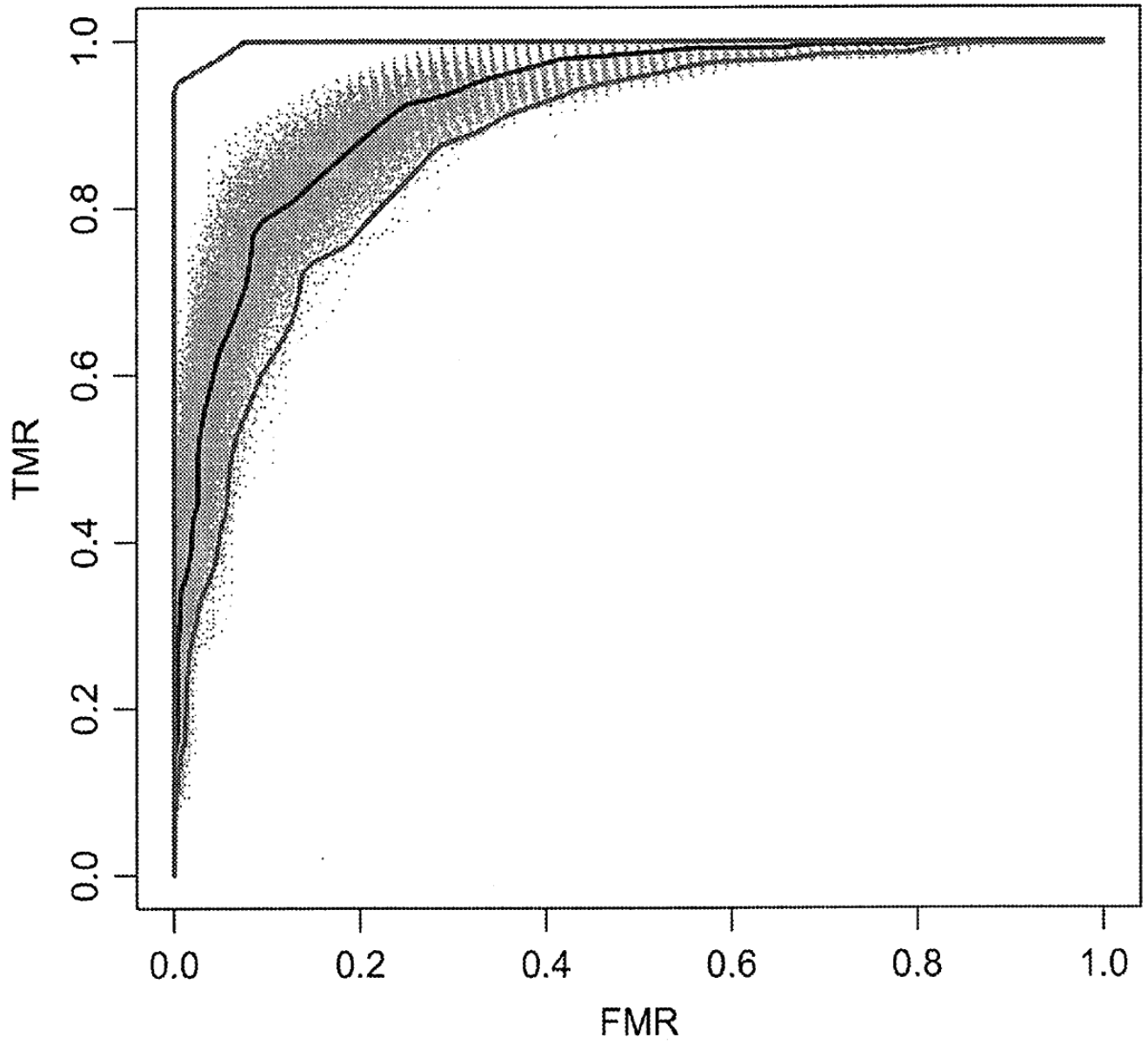
http://biometrics.derawi.com/?page_id=51

On the comparison of ROC curves



[Chul Lee 2011]

Confidence intervals in the ROC curve



[Schukers 2010]

Expected Performance Curves

Algorithm 1 Method to generate the Expected Performance Curve

Let *devel* be the development set
Let *test* be the test set
Let $V(\theta, D)$ be the value of V obtained on the data set D for threshold θ
Let $C(V1(\theta, D), V2(\theta, D); \alpha)$ be the value of a criterion C that depends on α, and is computed on the data set D
for values $\alpha \in [a, b]$ where a and b are reasonable bounds **do**
  $\theta^\star = \arg\min_\theta C(V1(\theta, devel), V2(\theta, devel); \alpha)$
  compute $\mathrm{V}(\theta^\star, test)$
  plot $\mathrm{V}(\theta^\star, test)$ with respect to α
end for

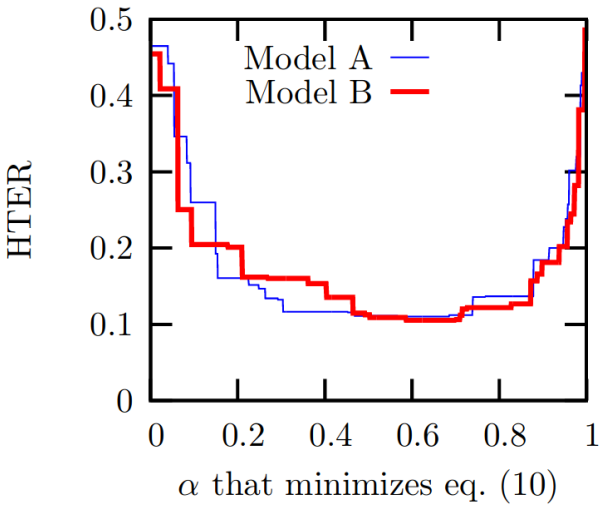
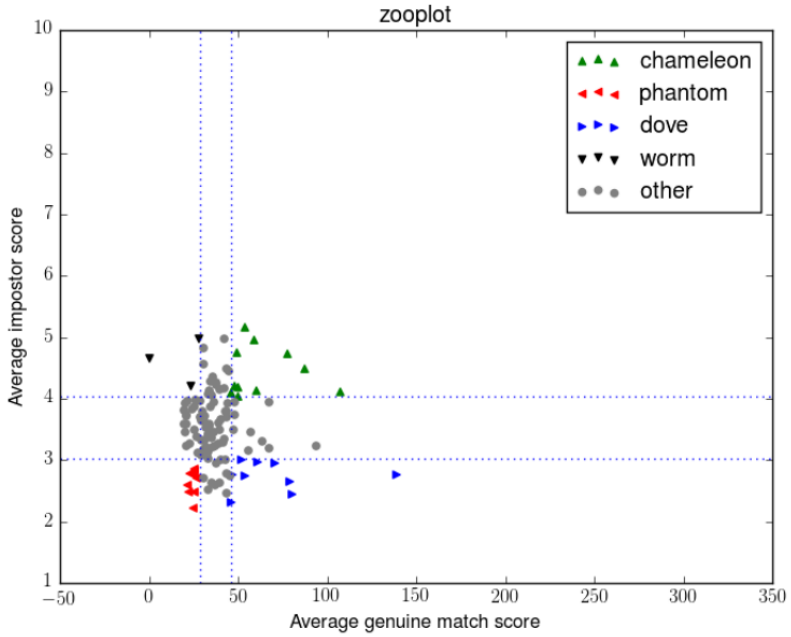
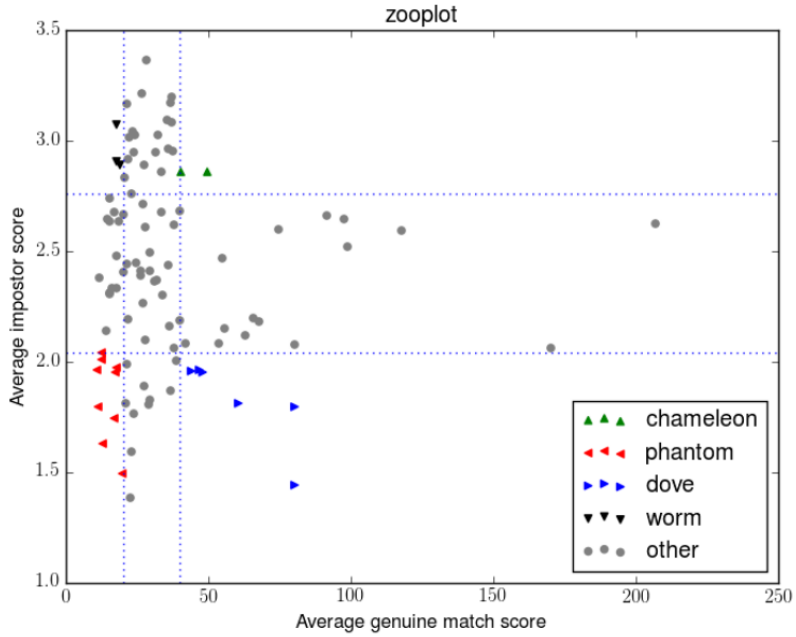


Figure 4. Expected Performance Curves for person authentication, where one wants to trade-off false acceptance rates with false rejection rates.

[Bengio et al. 2005]

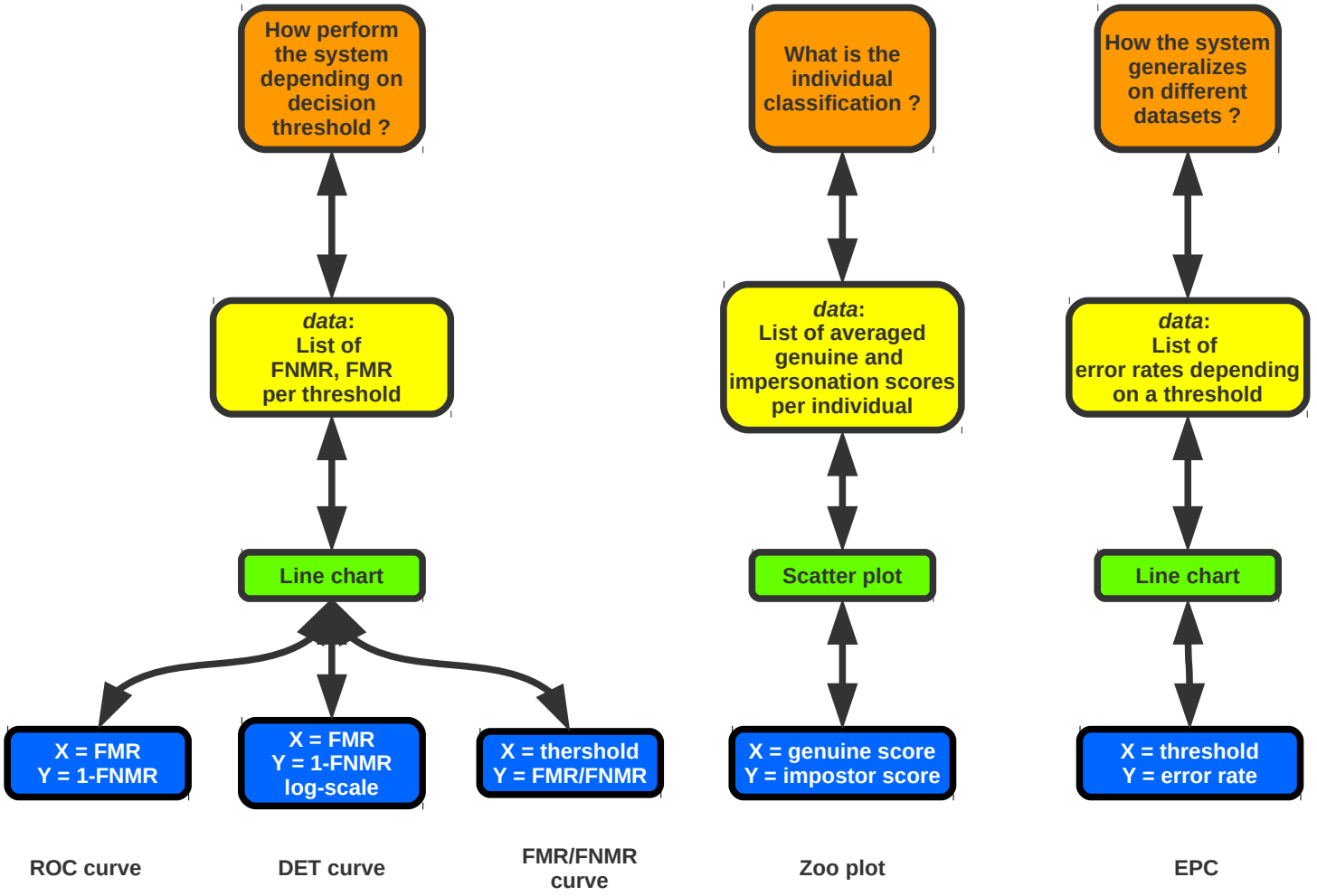
Zoo Plot – a local approach





[Yager 2010]

Nested blocks and guidelines model



Discussions on these common methods

- ROC, EPC, Scores distribution
  - Global information
  - => problematic threshold configuration can be identified
  - => Impossible to identify the problematic individuals
- Zoo plot
  - Individual information
  - => BUT screen space not well used
  - Possible to identify the problematic individuals
  - => BUT impossibility to understand why
- EPC
  - Allows to see generalization on other datasets
  - Hard to read and understand
- All of them
  - Lack of information to understand the reasons of failures

Additional issues to the ROC curve

- There are several ways to compute the ROC curves
  - Some are exact [Fawcett 2006] (and fast)
  - Most are inexact (and probably slower)
- Papers are never clear on the used algorithm (but it mostly seem it is the inexact way)
  - So most of ROC curves are partly lying on the results they show

Some propositions of novel evaluation methods for biometric authentication

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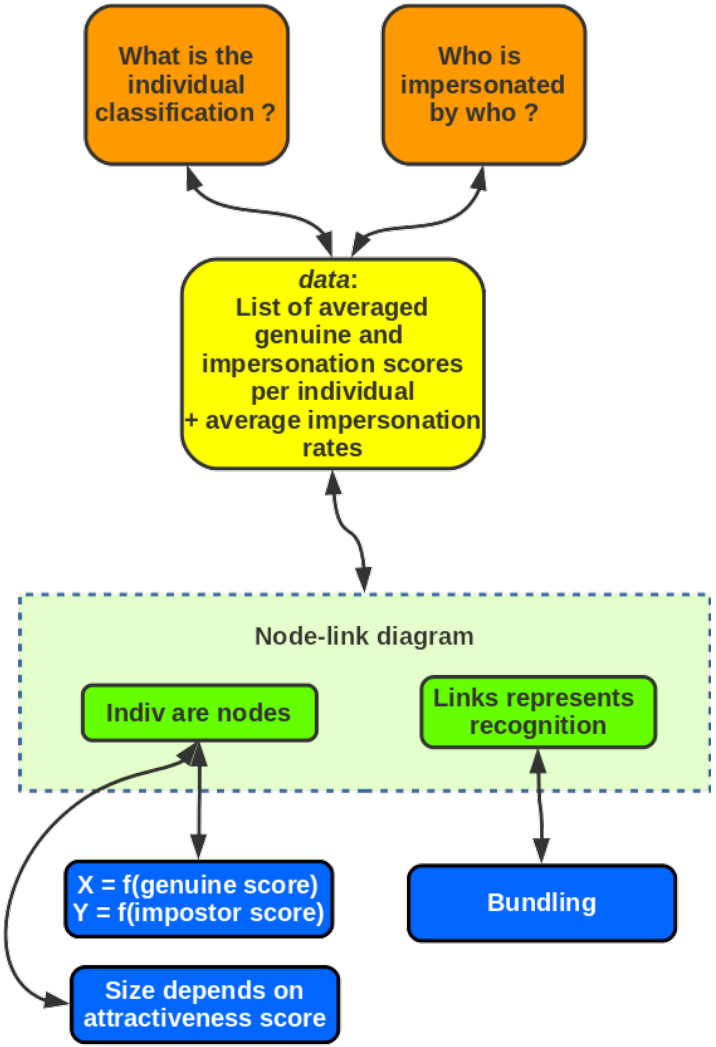
Zoo Graph – an extended Zoo plot

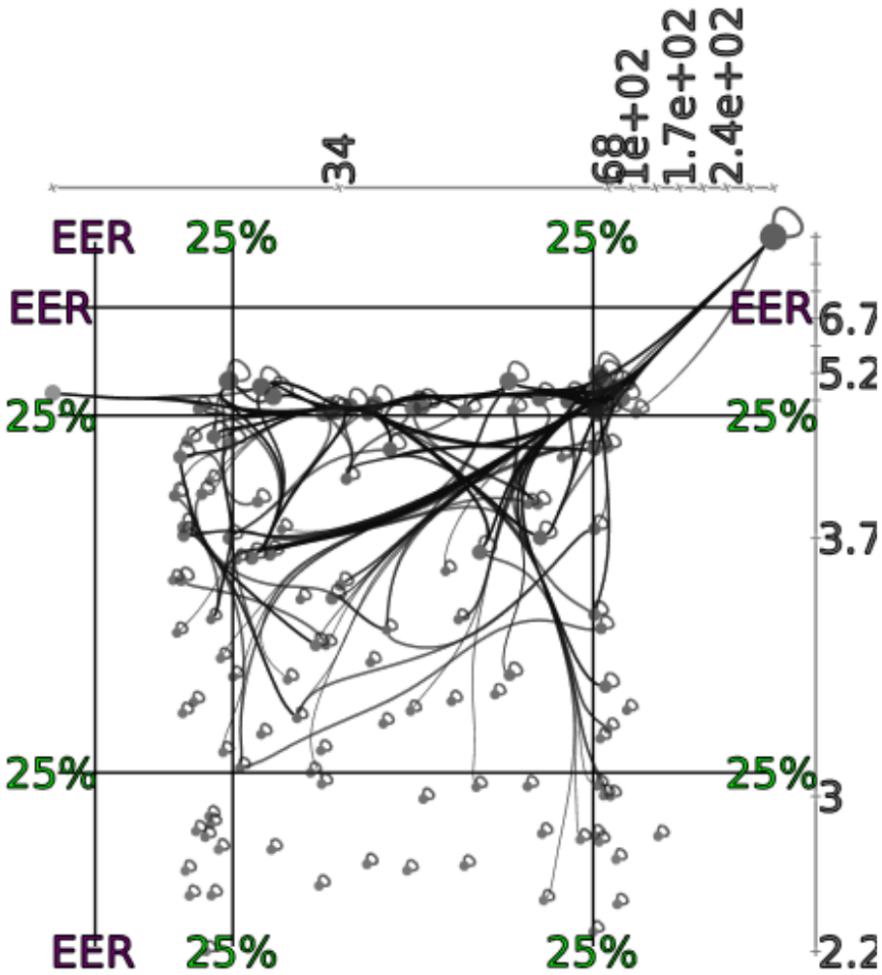
- Purpose
  - Easily track the problematic individuals
  - Easily track the impersonating relations between individuals
- Idea
  - Zooplot shows problematic individuals
  - But not relations between them
    - So add links to show impersonation ability
  - Provide space equally for individuals
    - Apply a specific non linear mapping

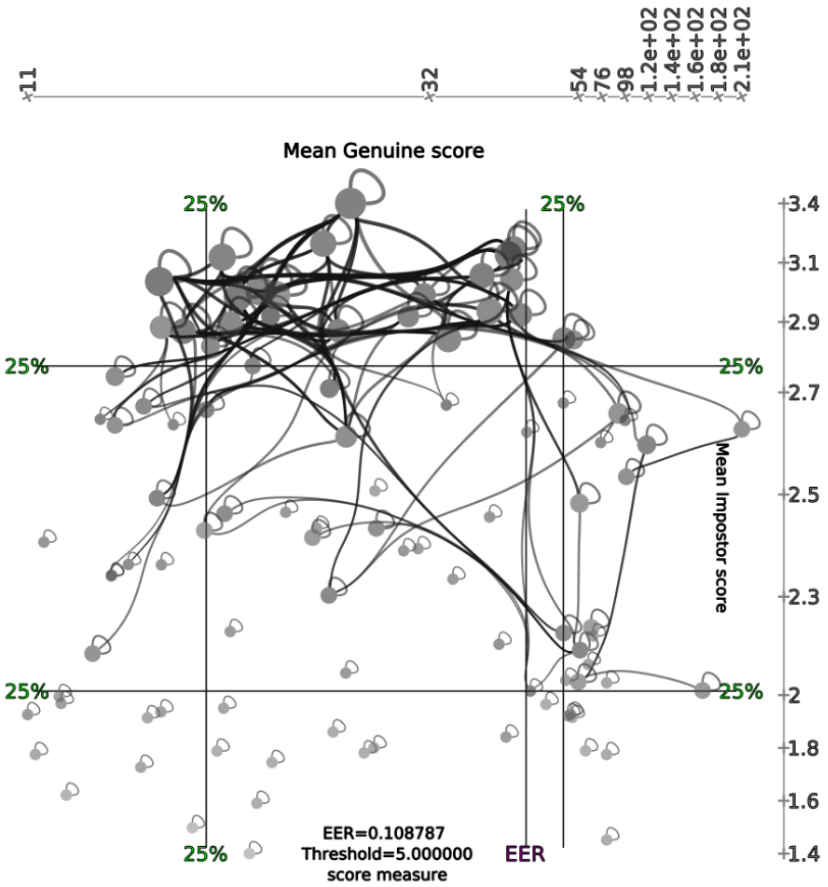
Zoo Graph – an extended Zoo plot



Zoo Graph

Zoo Graph – an extended Zoo plot





[Giot et al. 2016]

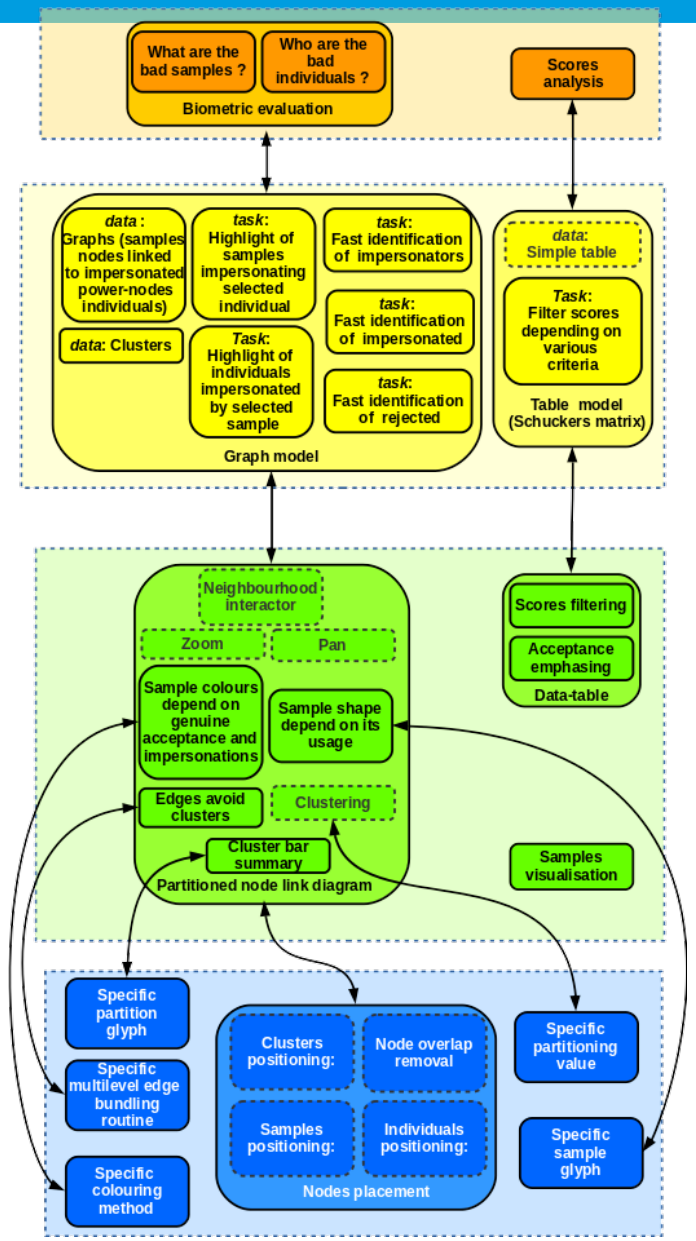
Discussion on the Zoo Graph

- Advantages
  - The non-linear mapping of individuals position reduces overlapping (and help to better estimate the distribution)
  - The edges as well as the nodes size highlight the bad individuals
- Limits
  - Does not scale well when there are more than 10% of FMR (hair ball effect)
  - Edges are computed on averaged scores => the drawing can be over-optimistic

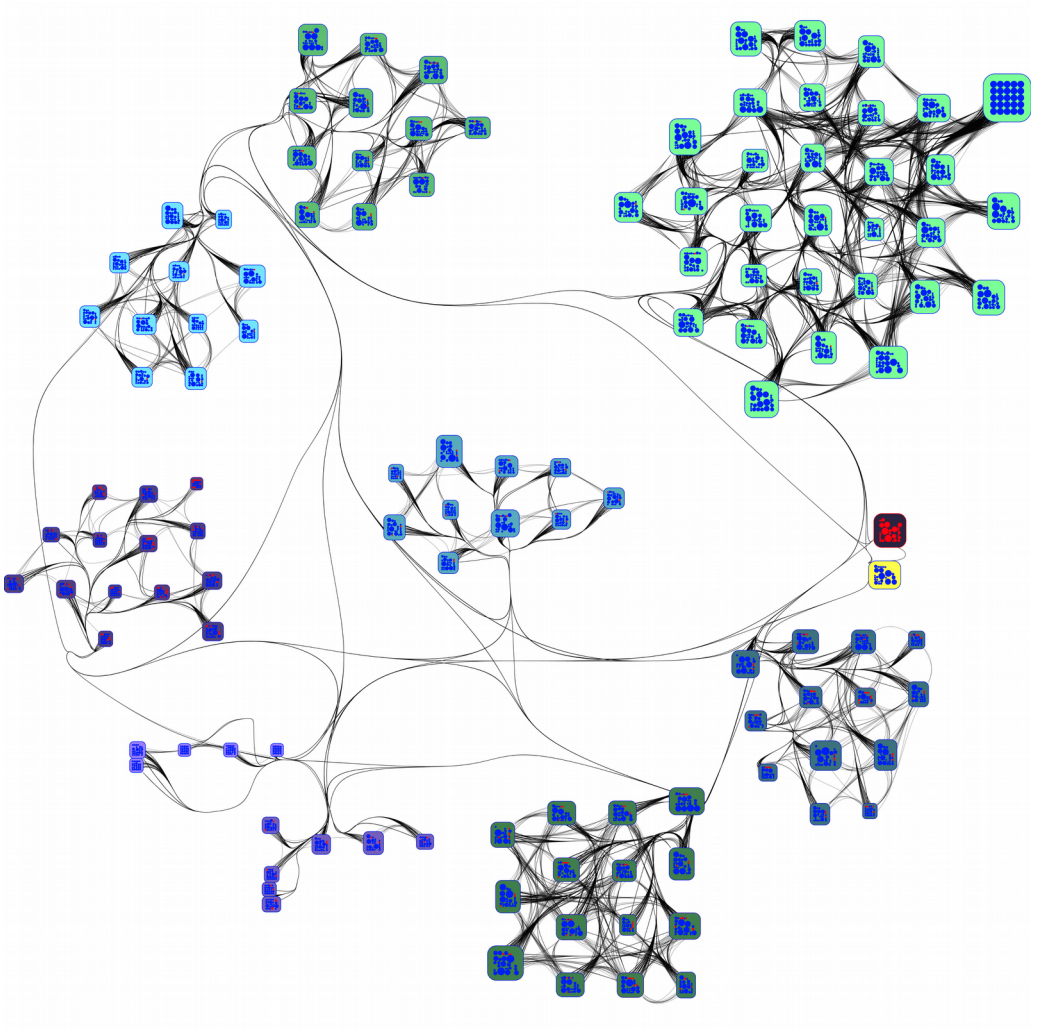
Biometric Power Graph – Sample analysis

- Purpose
  - Easily track the problematic individuals
  - AND easily track the problematic samples
  - Easily track the impersonating relations between individuals
- Idea
  - Enhance Zoo Graph by displaying the samples
  - Cluster the individuals based on their biometric behavior
  - Use graph layout methods instead of an ad hoc projection

Biometric Power Graph – Sample analysis

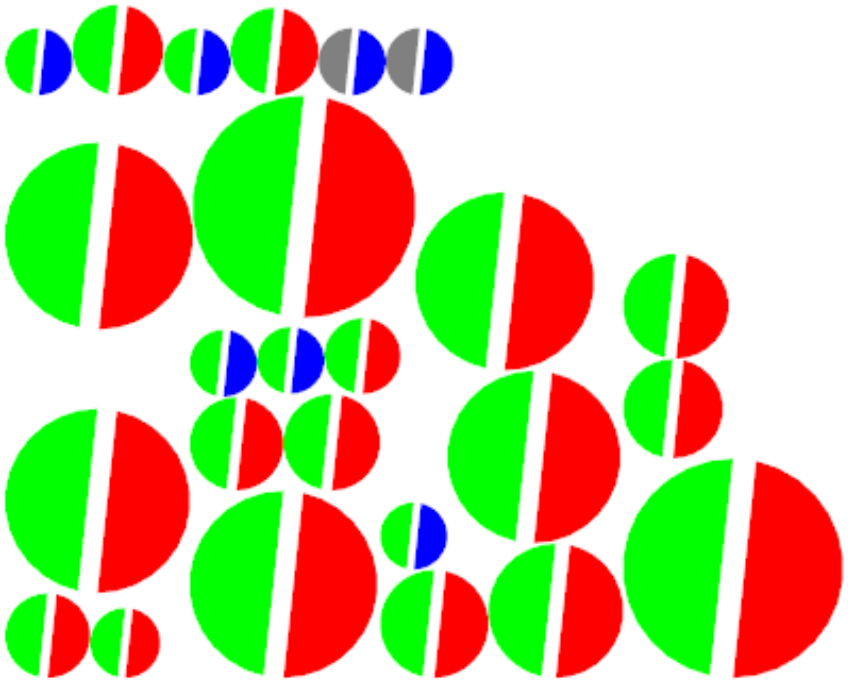


Biometric Power Graph



[Giot et al. 2017]

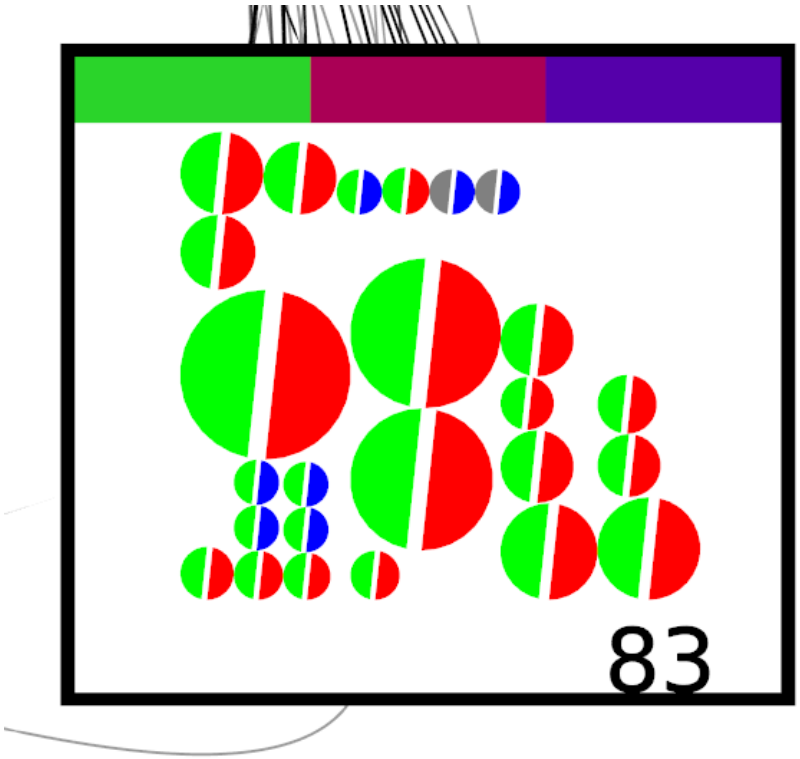
Biometric Power Graph – better encodings



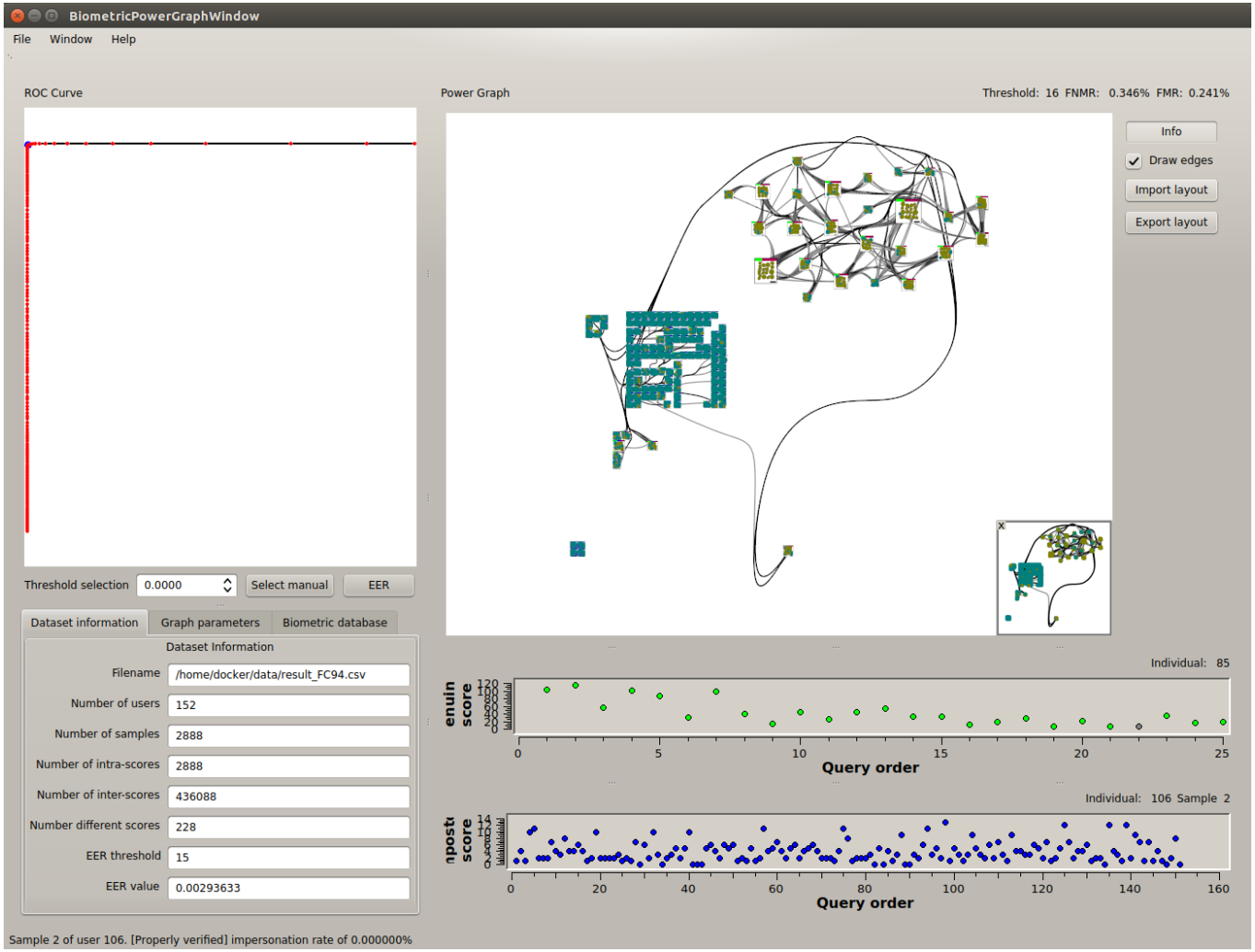
- Each sample provides its
  - Inability to be verified
    - green/gray
  - Ability to impersonate others
    - blue/red
  - Ratio of impersonation
    - size

Biometric Power Graph – better encodings

- Each individuals provides its
  - FMR
    - for attacks
    - when attacked
  - FNMR



Biometric Power Graph



Discussion on the Biometric Power Graph

- Advantages
  - Clear identification of problematic samples
  - Clear identification of different individual behaviors
- Limitations
  - Huge drawing size => interaction is mandatory
  - More complex to handle than standard methods
  - The display is CPU/GPU intensive and does not parallel well on GPU because of edge bundling that plots too many things at the same pixel location

Conclusion

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Consideration of the new visualizations

- Few works in the literature try to bring new visual evaluations (or improve existing ones)
  - ROC curve visualization can be improved (addition of score distribution)
  - No visualization targets spoofing attacks
  - No visualization targets user behavior in template update systems
- Zoo graph and biometric power graph visualizations are promising, but
  - The cognitive effort to understand them is far more important than for the ROC curve
  - The computational power needed to compute them is for more important than for the ROC curve

Conclusion

- Biometric authentication systems need to be evaluated
- This can be done helped with graphics
- Main visualizations work well to give the performance of the system but **fail to explain their failures**
- Some visualizations have been created to overcome these issues but still need to be improved
- Some sub-research fields still need to be explored to improve the state of evolution

Questions

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