Information Visualization

Introduction

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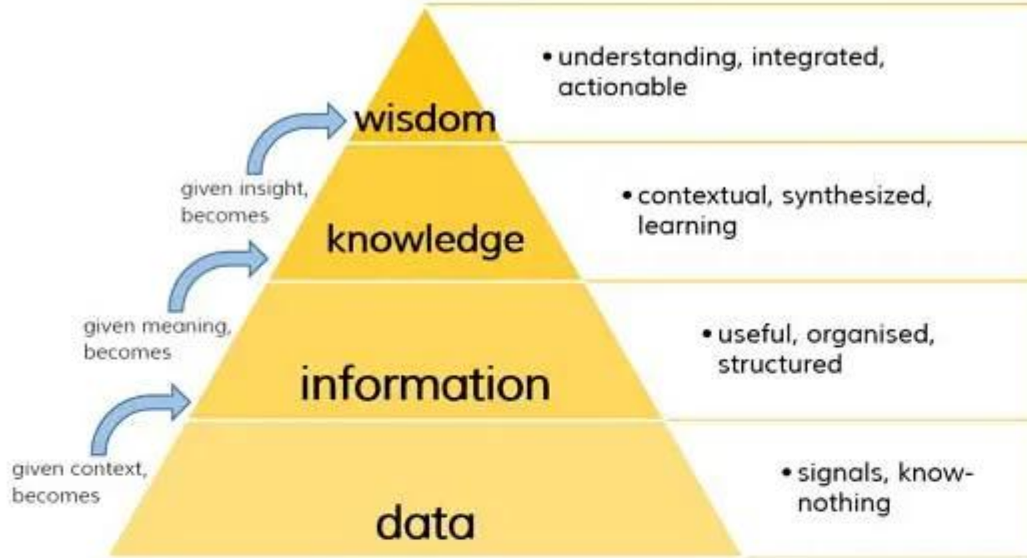
Data, information and knowledge



- Data consists of raw symbols;
- - Information is data that is giv
  'who, what, where and when q
- - Knowledge is the application
  answers to the 'how questions
- - Wisdom is the understanding of the knowledge, being integrated and actionable.
- Rowley, J. (2007). The wisdom hierarchy: Representations of the DIKW hierarchy. *Journal of Information Science*, *33*(2), 163–180. https://doi.org/10.1177/0165551506070706

“Graphics *reveal* data”

- John Snow’s map of water wells in London (1854)

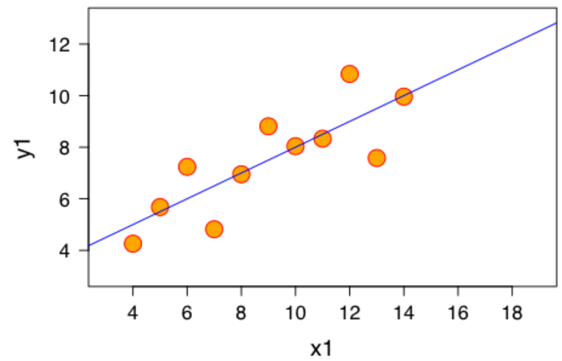
Tufte, Edward. *The Visual Display of Quantitative Information*. Cheshire, Graphics Press, 2001, 2nd edition

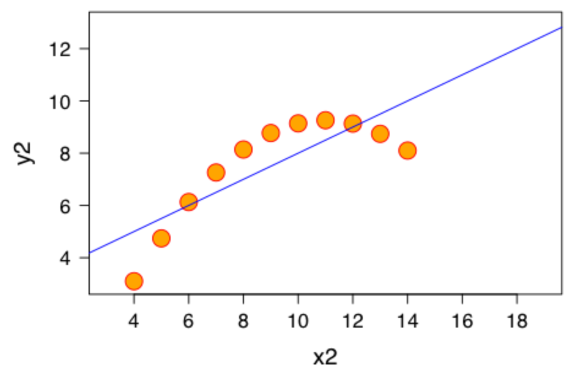
causality

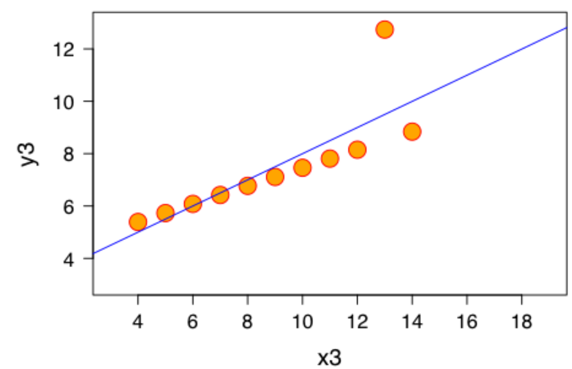
Basics

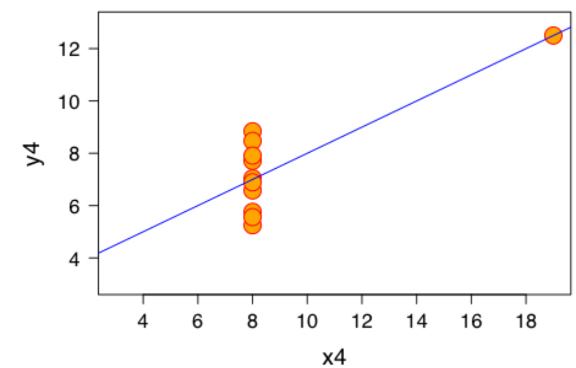
Anscombe's Quartet: Raw Data

	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
mean	9.0	7.5	9.0	7.5	9.0	7.5	9.0	7.5
var.	10.0	3.75	10.0	3.75	10.0	3.75	10.0	3.75
corr.	0.816		0.816		0.816		0.816	





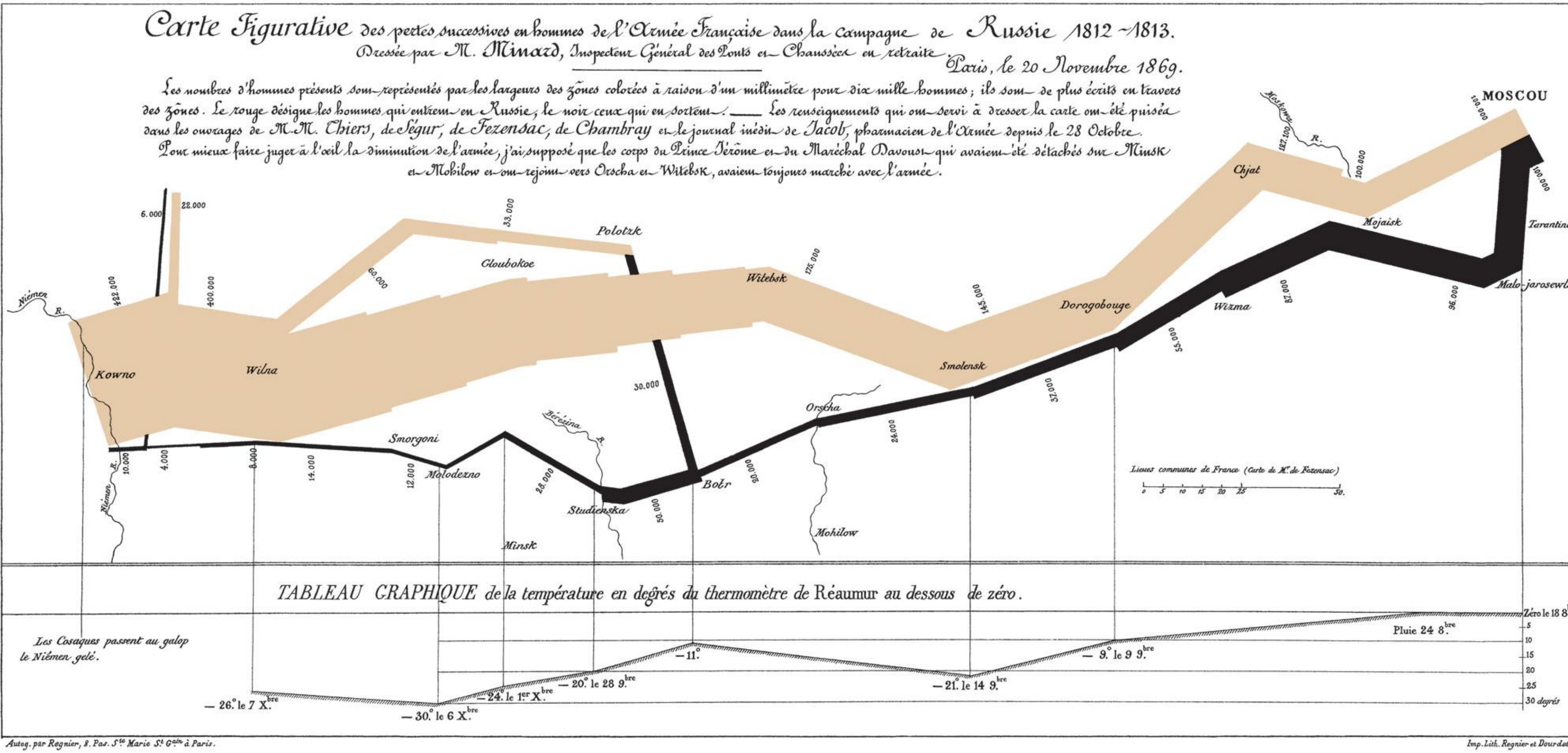




Anscombe, F.J. *Graphs in Statistical Analysis*. American Statistician 27 (1973), 17–21

Show differences, similarities and patterns

Adding complex data



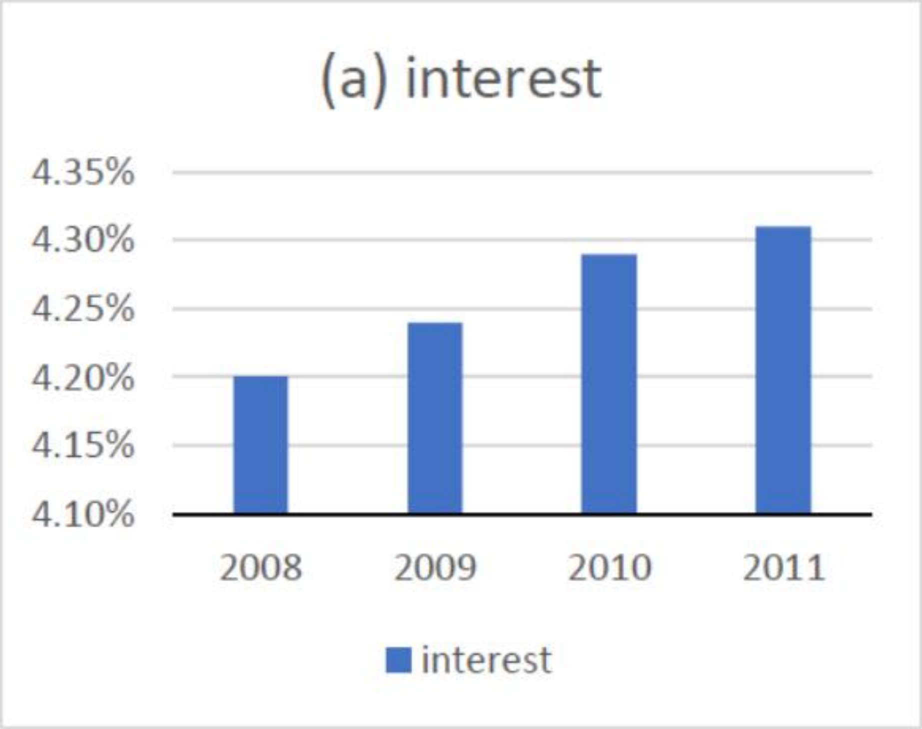
Charles Joseph Minard's map (1869)
1 mm = 6 mil people

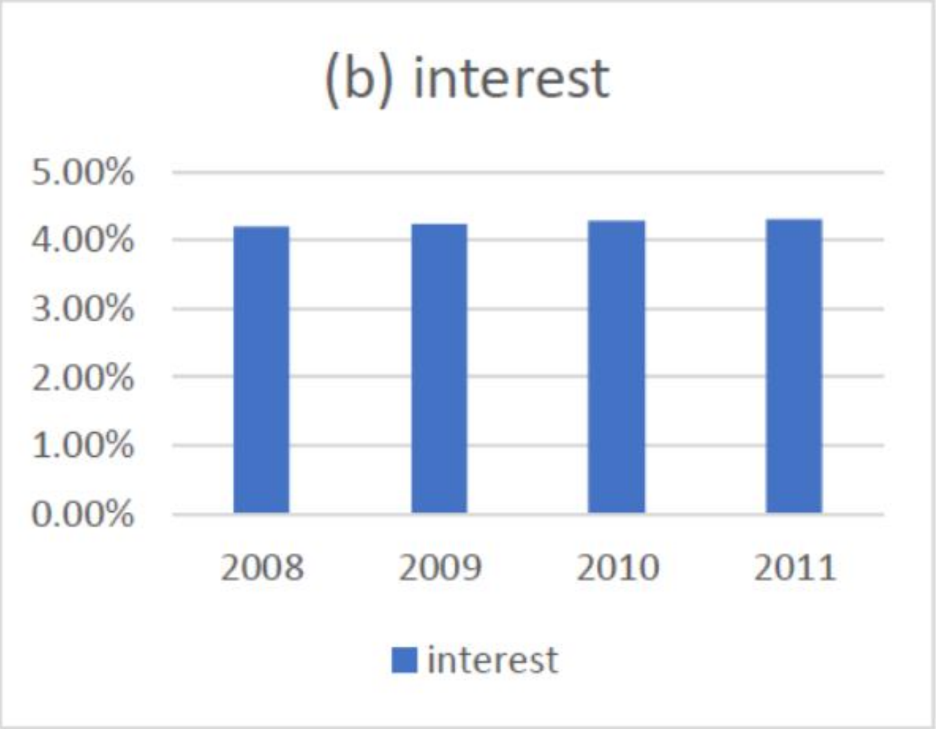
Communicating data

https://www.youtube.com/watch?v=jbkSRLYSojo

‘Misleading’ with data visualization

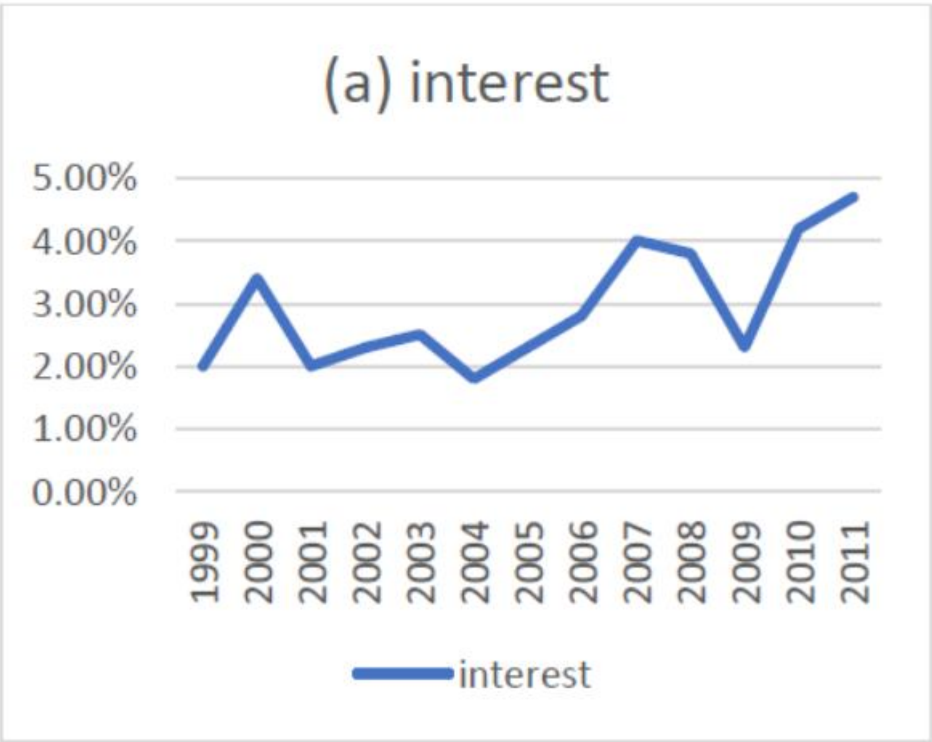
- *Example of a truncated y axis, where the increase in interest in (a) seems quite large, whereas the actual increase (b) is almost unnoticeable (graphs created in excel)*

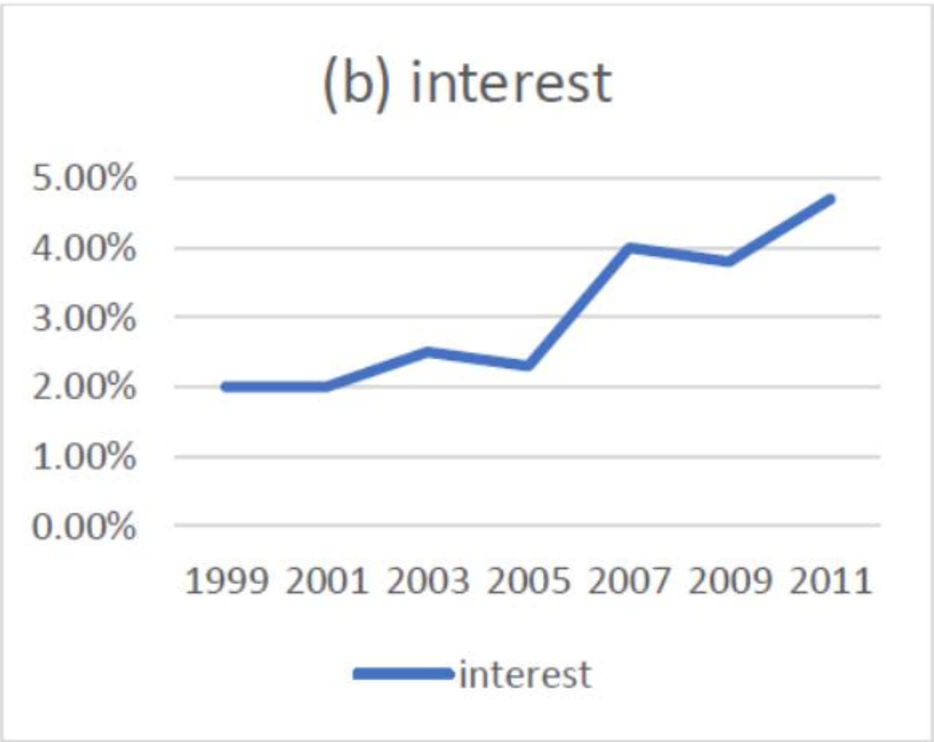




'Misleading' with data visualization

- *Example of omitting data, where (a) shows the original data source, and (b) shows half of the data of (a), creating a trend that cannot be seen in (a) (graphs created in excel)*

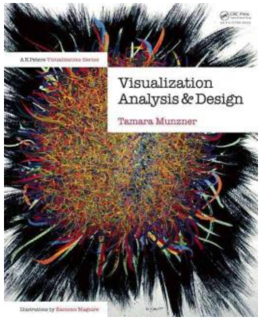




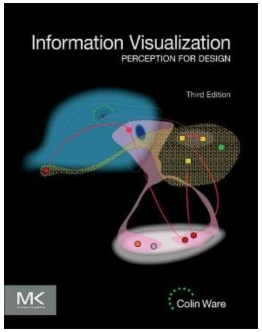
- A final example is the correlation – causation issue. Correlation does not imply causation. Nevertheless, a correlation is often seen as a causation, for example by internet articles with headers such as *“People drinking beer live longer; drinking beer is healthy!”.*

References

- Tamara Munzner. Visualization Analysis and Design. AK Peters Visualization Series, CRC Press (2014).



- Colin Ware. Information Visualization, Third Edition: Perception for Design (Interactive Technologies). Morgan Kaufmann. 536 pages (2012)



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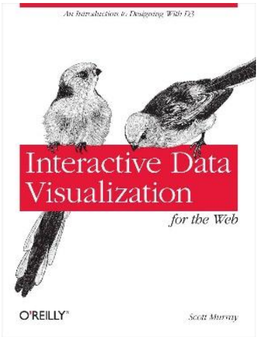
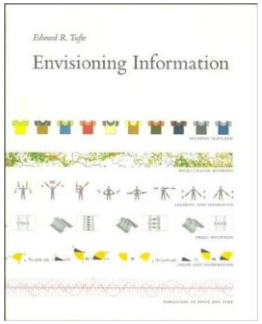


- Edward Tufte. The Visual Display of Quantitative Information. 1983



Objectives:

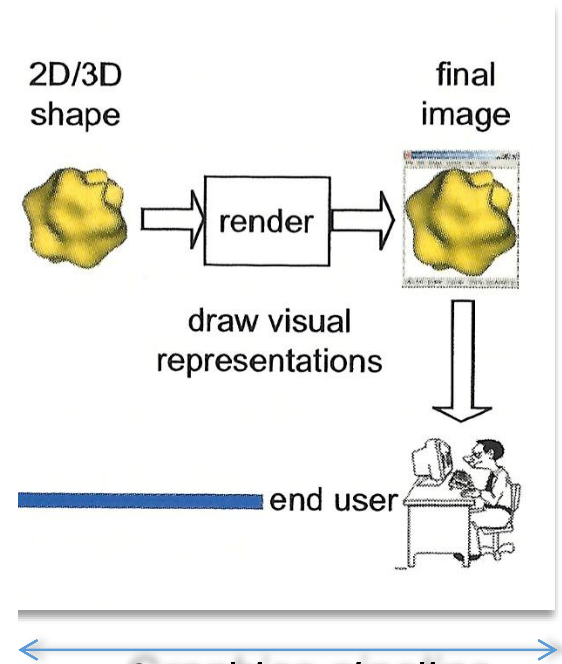
- The goal is to present information visualization techniques and apply them to solve problems related to the interaction with large datasets
- Understand the principles of information visualization
- Know the Schneiderman’s mantra of information visualization
- Know the main information visualization techniques
- Know the tools for dealing with information visualization
- Know the data structures used to visualize data
- Implement a pipeline for information visualization
- Interact and use different information visualization techniques
- Be able to reuse information visualization techniques available
- Be able to program basic information visualization techniques

Planning

- Contents:
  - Introduction to information visualization
  - Information visualization pipeline
  - Information visualization techniques (ex. graphs, hierachies, multidimensional data, …)
  - Data processing
  - Programming of information visualization techniques

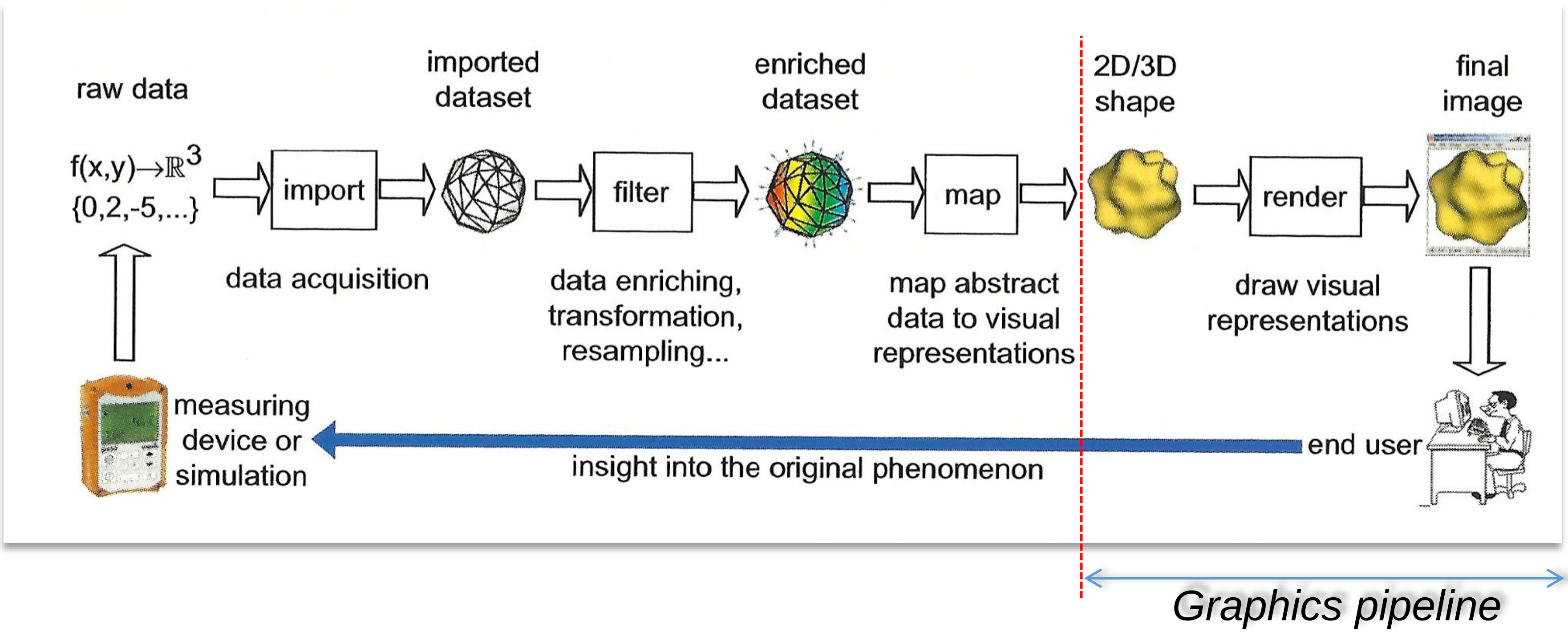
Information visualization
x
Computer Graphics

The domain



Graphics pipeline

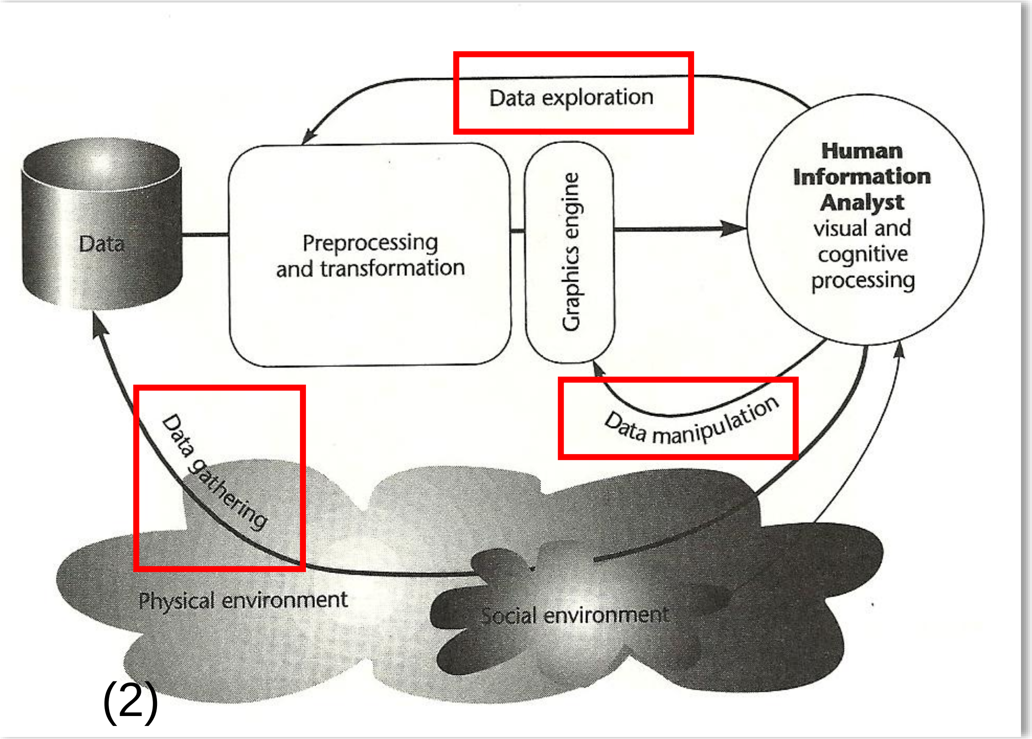
The domain



Telea, A.C. *Data Visualization – Principles and Practice*. Wellesley, MA: A K Peters, 2008

The domain

- Visualization is the communication of information using graphical representations [(1)].

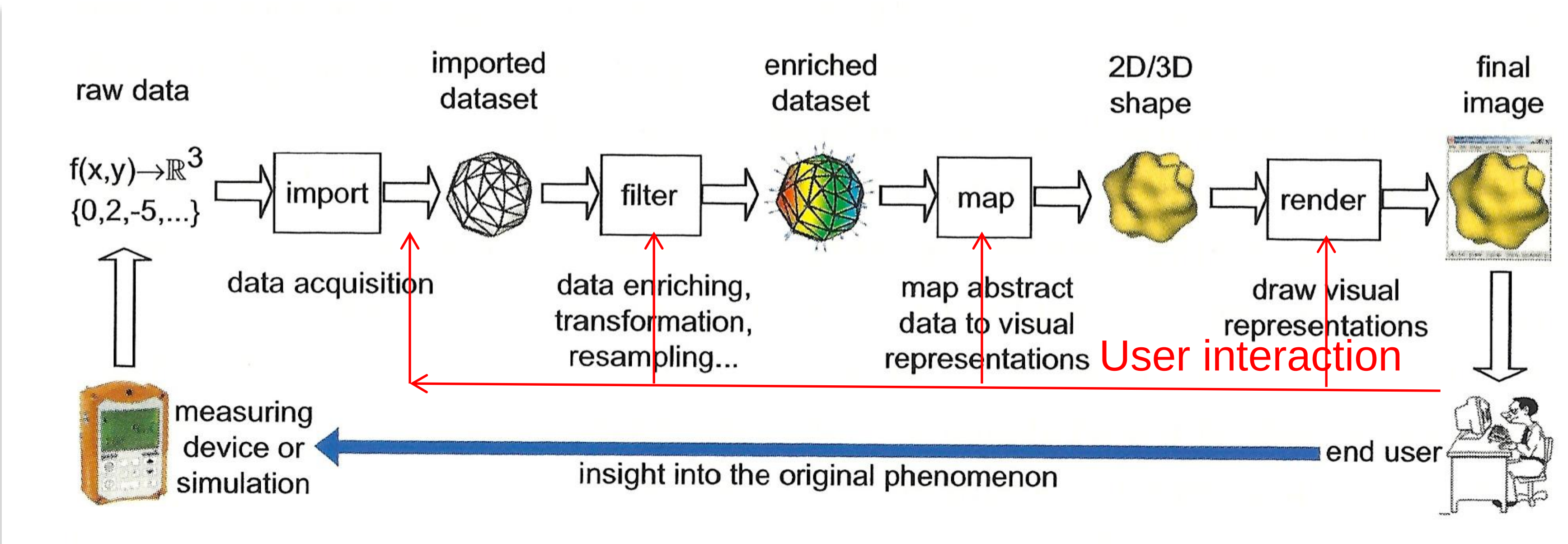


(2)

(1) Ward, M., Grinstein, G e Keim, D. *Interative Data Visualization – Foundations, Techniques and Applications*. Wellesley, MA: A K Peters, 2010

(2) Ware, Colin. *information Visualization – Perception for Design*. San Francisco, CA: Morgan Kaufmann, 2000

The domain



Telea, A.C. *Data Visualization – Principles and Practice*.
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Principles of data visualization

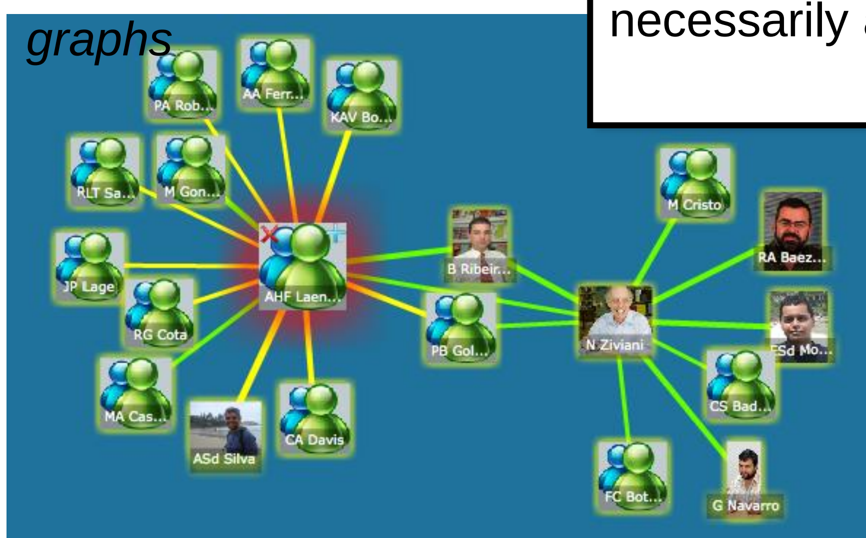
- **Characterizing data**
- User perception
- Users task and interaction

Scientific data: information associates with positions/regions of a space (implicit or explicit geometry)

Abstract data: information associated to an entity of an application domain, not necessarily a spatial one

Trajectories

Social graphs



Characterizing data

- Many classifications…

Keller e Keller (1994)

- Scalar (or scalar fields
- Nominal
- Direction
- Shape
- Position
- Region

Keller, P. e Keller, M. *Visual Cues: Practical Data Visualization*. IEEE Computer Society Press, 1994

Shneiderman (1996)

- Unidimensional
- Bidirectional maps
- Tridimensional world
- Temporal
- Multidimensional
- Trees
- Networks

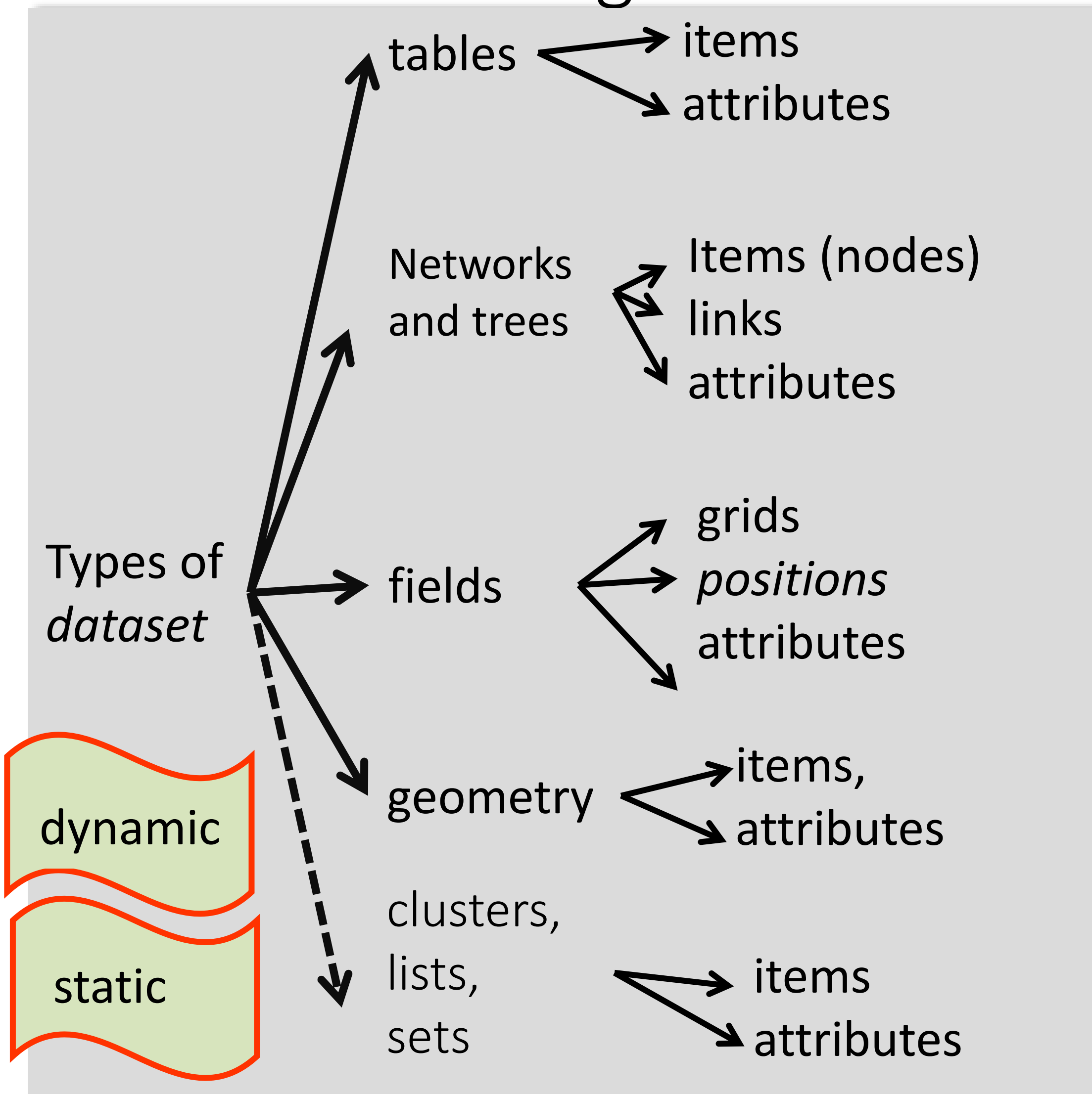
Shneiderman, Ben *The Eyes Have it: A Task by Data Type Taxonomy for Information Visualization*. 1996 IEEE Symposium on Visual Language, pp336-343

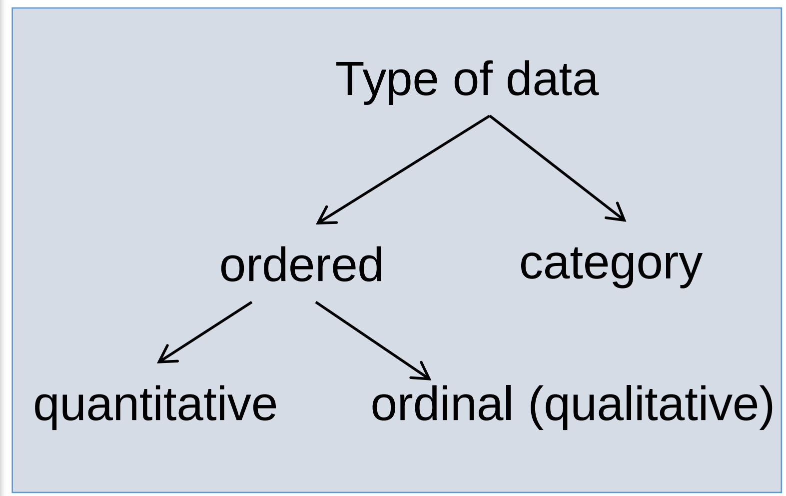
Keim (2002)

- Unidimensional
- Dimensional
- Multidimensional
- Text and hypertext
- Hierarchy and graphs
- Algorithms and software

Keim, Daniel *Information Visualization and Data Mining*. IEEE Transactions on Visualization and Graphics, 8:1(2002):1-8

Characterizing data

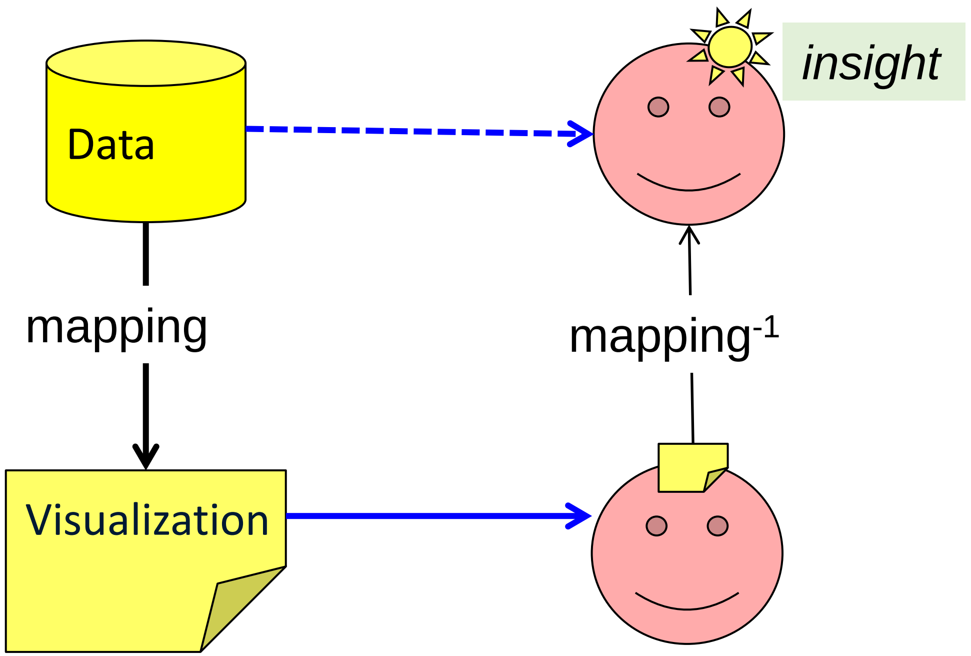




Munzner, Tamara *Visualization Analysis and Design*. Boca Raton, FL:Taylor & Francis, 2014

Principles of data visualization

- Characterizing data
- User perception
- Users task and interaction

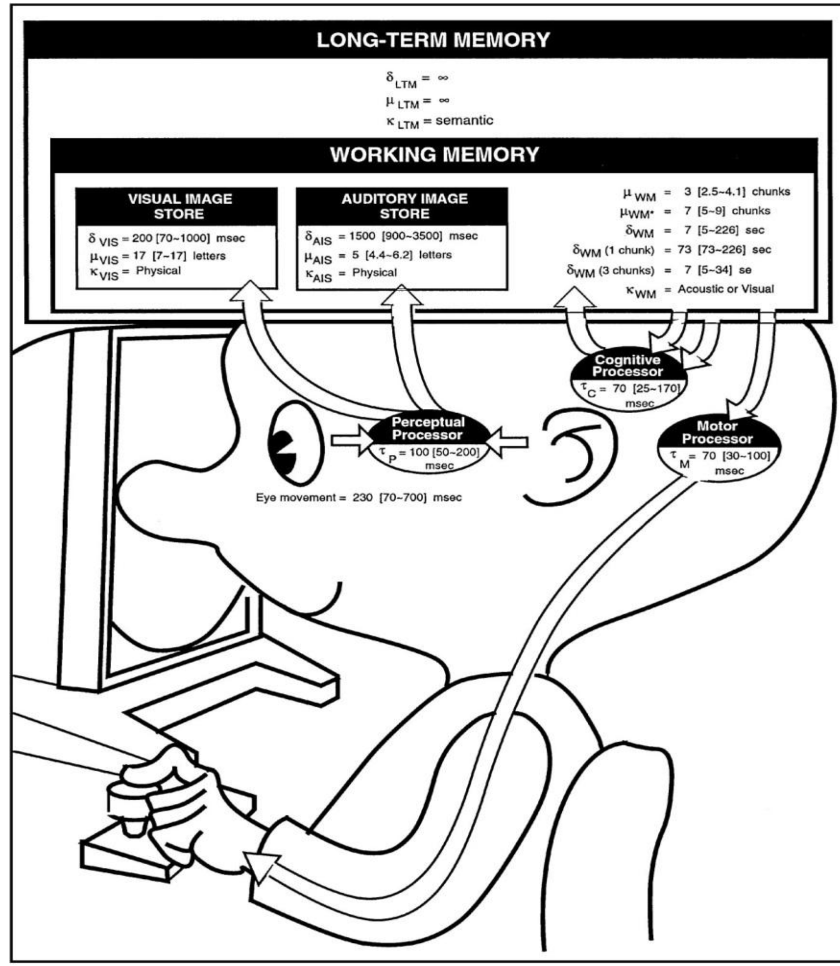


Process by which we interpret what is around us to create a mental representation of evidences

recognize, organiza and interpret sensorial information

Model of Human processing

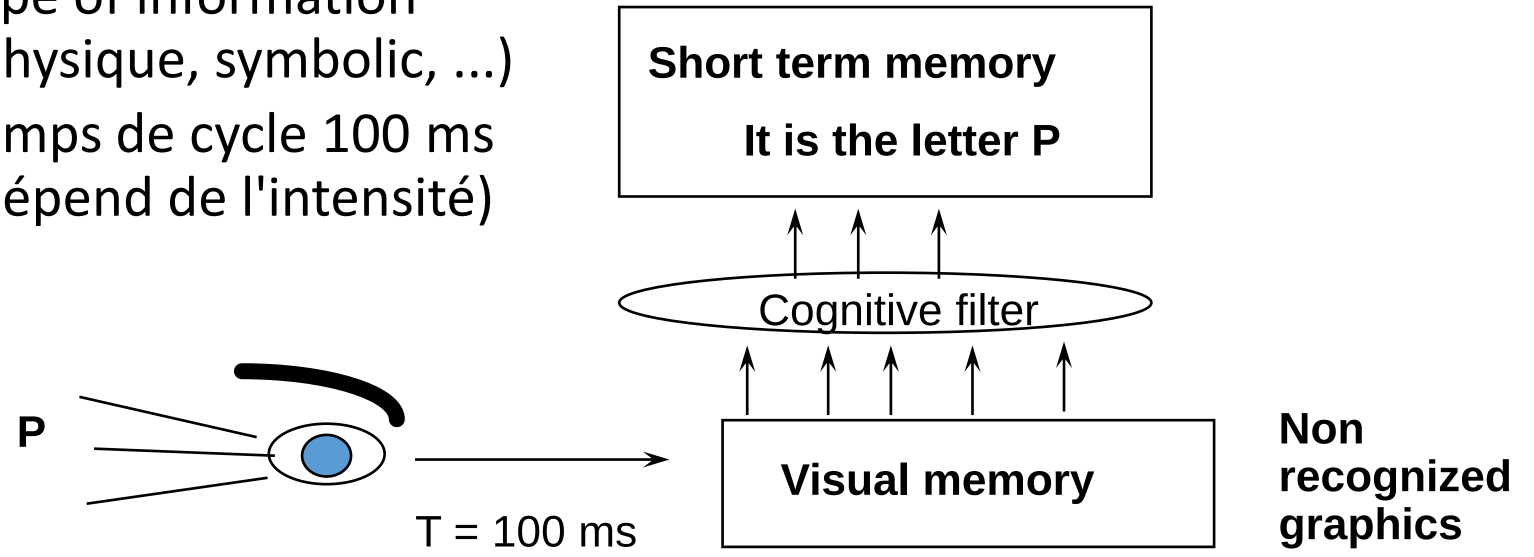
- Perceptive (every sense)
- Cognitive (memory + processing)
- Motor (movements, ex. Fitts' law)



Card, S.K; Moran, T. P; and Newell, A. *The Model Human Processor: An Engineering Model of Human Performance.* In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), **Handbook of Perception and Human Performance.** Vol. 2: Cognitive Processes and Performance, 1986, pages 1–35.

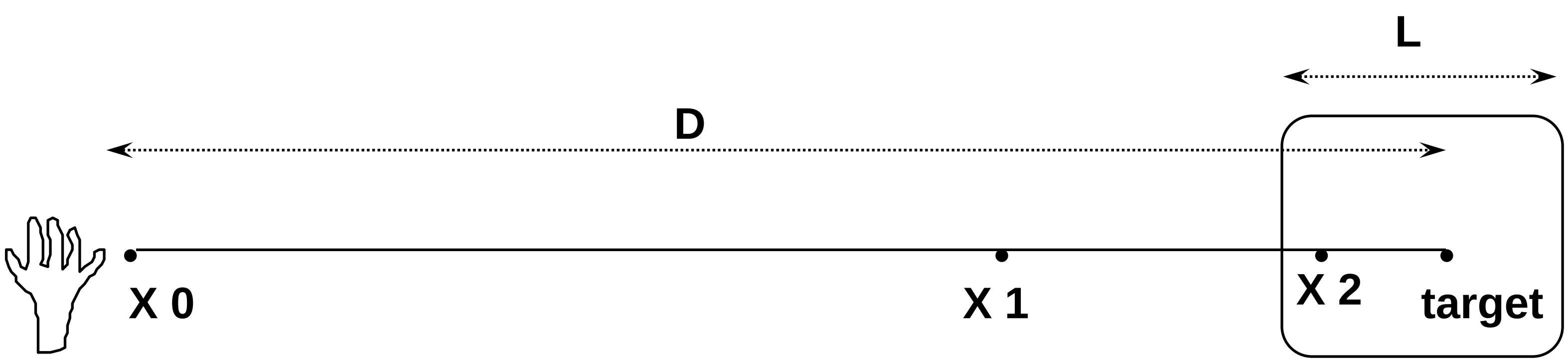
Perceptive system

- Representation non interpreted of inputs
- Information persistency = 200 ms for the visual memory, 1500 ms for the auditory memory
- Capacity of storage
- type of information (physique, symbolic, ...)
- temps de cycle 100 ms (dépend de l'intensité)



Motor system

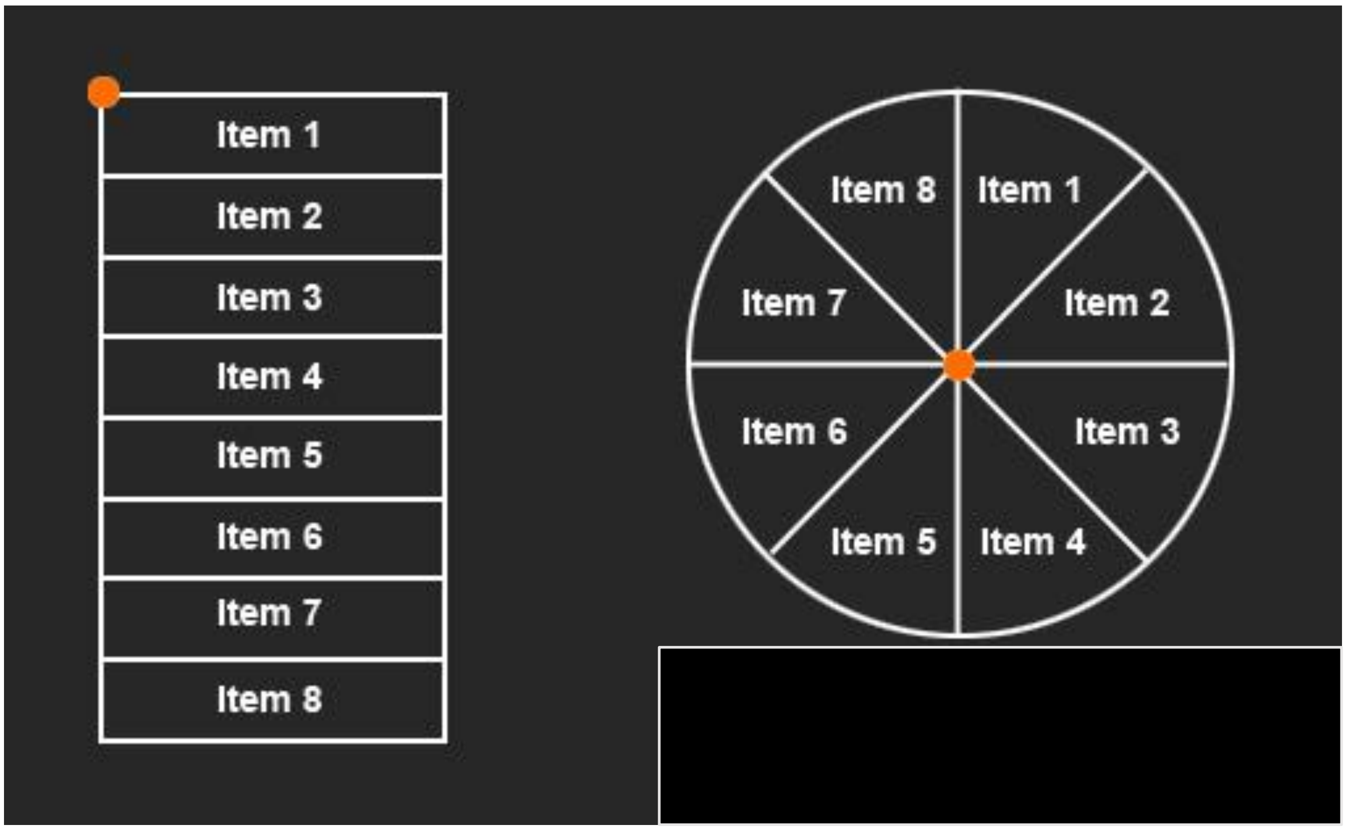
- Movements are not continuous pas a repetition of discreet micro-movements
- The movement corresponds to user interaction with physical devices
  - Time of micro-movement : 70 ms (cycle base of motor system)
  - Time of selection of a graphical element: T = I.log 2D/L with D : distance, L : size of the target, I = 0,1 sec. (Fitts' law 1954)



Paul M. Fitts (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, volume 47, number 6, June 1954, pp. 381–391. (Reprinted in *Journal of Experimental Psychology: General*, 121(3):262–269, 1992)

$$T = a + b\log_2\left(1 + \frac{2D}{W}\right)$$

Example


Item 1
Item 2
Item 3
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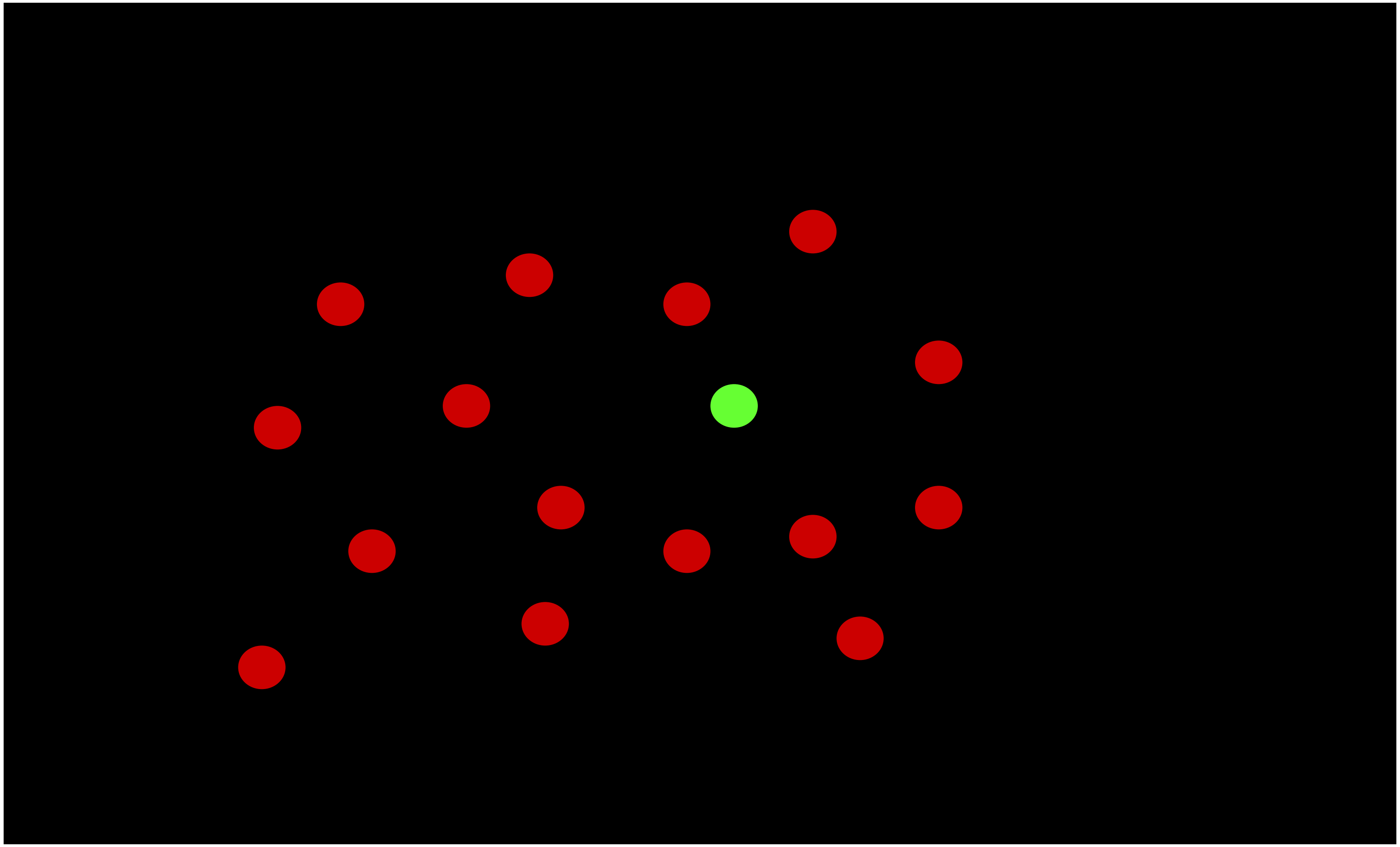
Item 4

facts about knowledge of perception

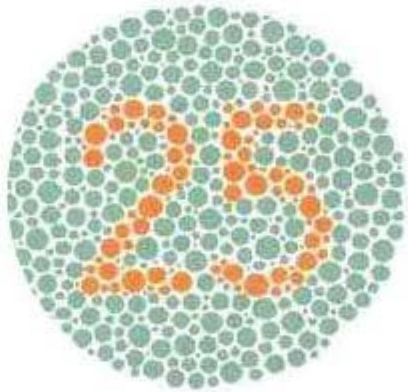
- We do not attend to everything that we see, logically since awareness of everything that we see would overwhelm us. In visualizations we should therefore strive to let meaningful information stand out in contrast to what's not worth our attention.
- Our eyes are drawn to familiar patterns; we see what we know and expect. Information visualization should therefore also be rooted in an understanding of how people think.
- Working memory plays an important role in human cognition but is extremely limited. We only remember the elements to which we attend. Information visualizations should therefore serve as an external aid to augment working memory.

Few, S. (2009). *Now You See It: Simple Visualization Techniques for Quantitative Analysis* (1st ed.). Analytics Press.

Perception



Perception



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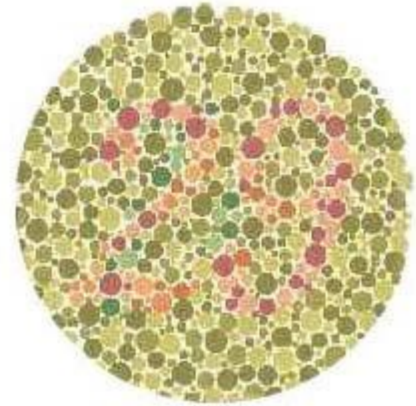

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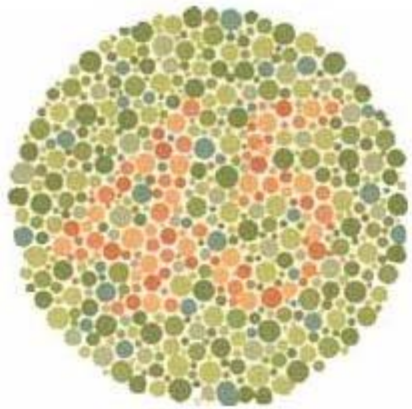

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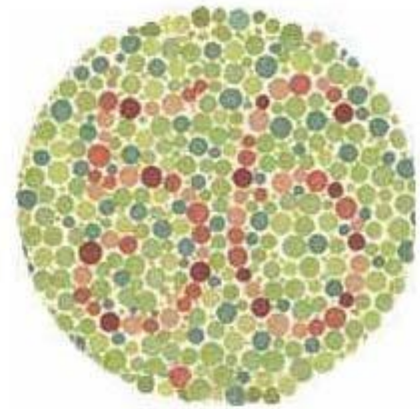

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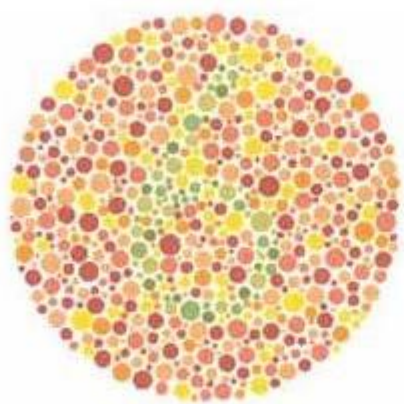

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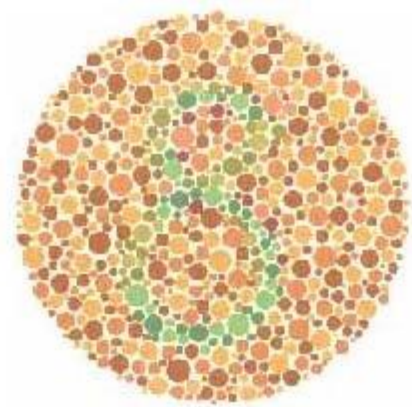

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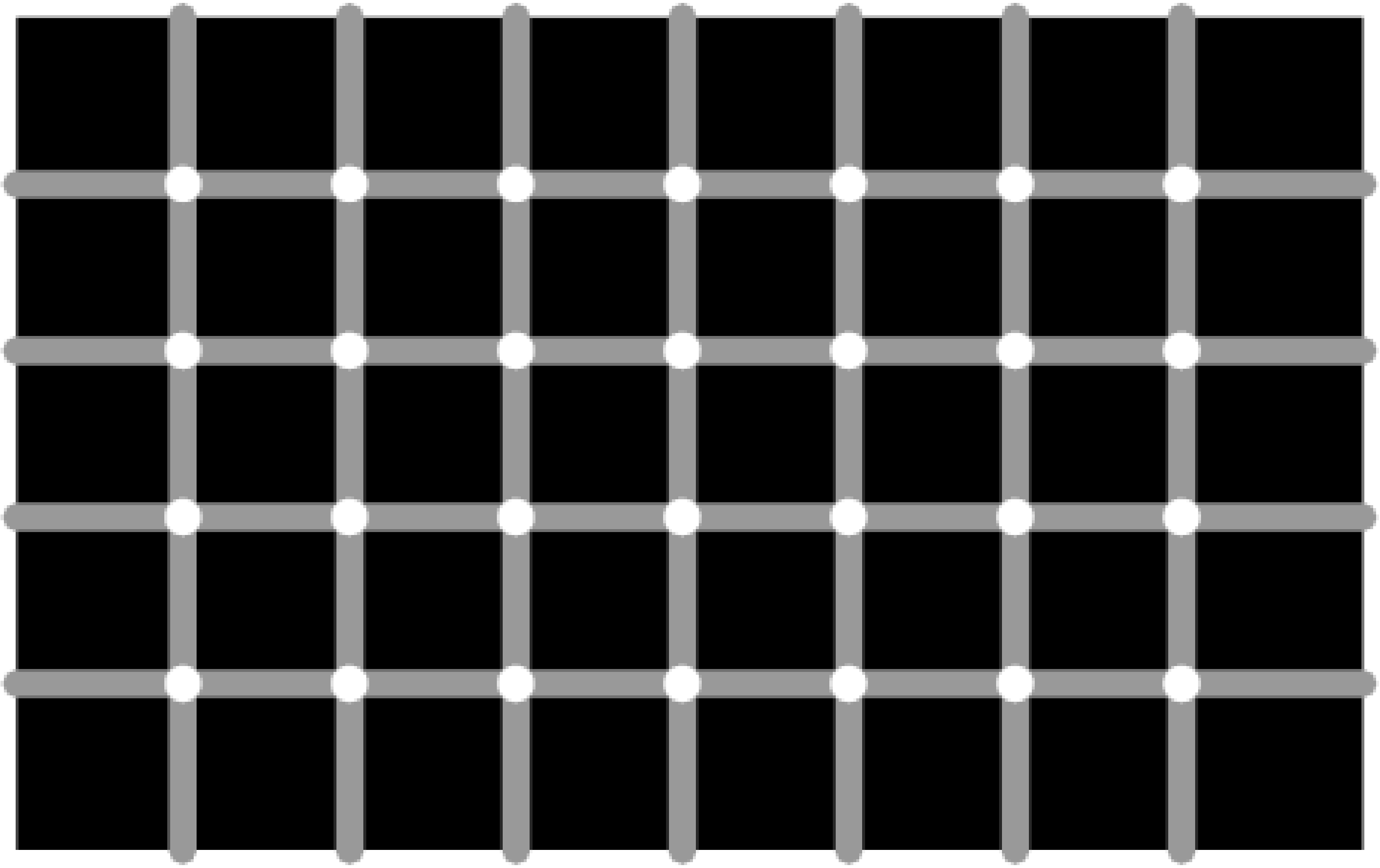
Perception

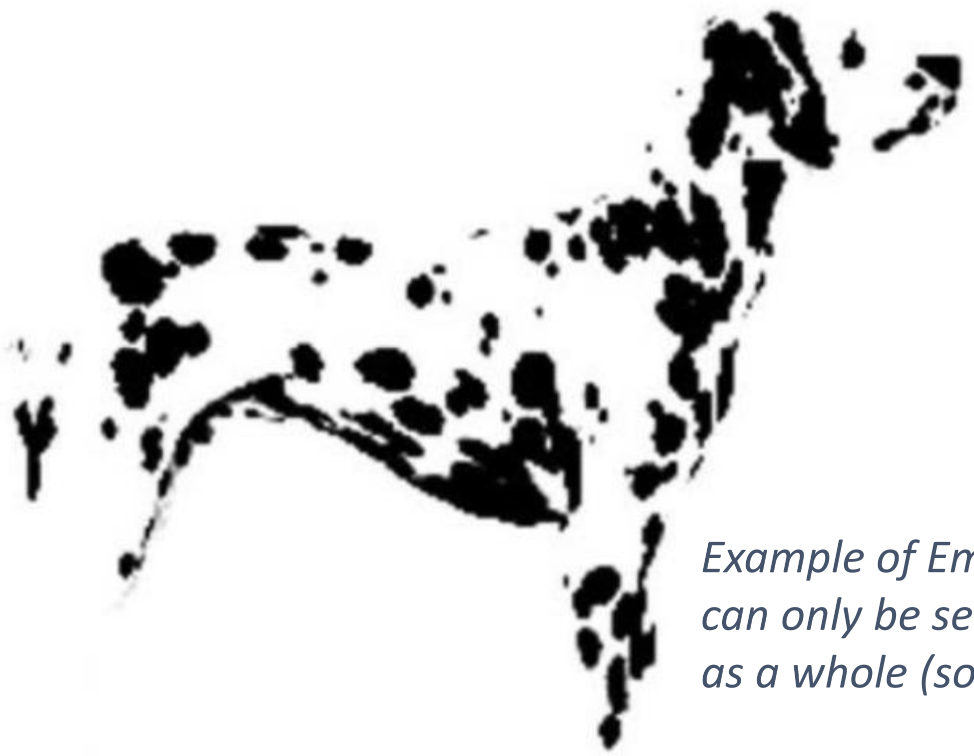


Gestalt principles of perception

- The gestalt psychology tries to understand the ability to acquire and maintain perceptions in an apparently chaotic world.
- The central idea is to view information as a whole rather than the sum of its parts.
- Applying gestalt principles on the design of information visualizations has a positive effect on the understandability.
- The key ideas of the gestalt psychology are the principles of emergence, reification, multi-stability and invariance.

The principle of emergence

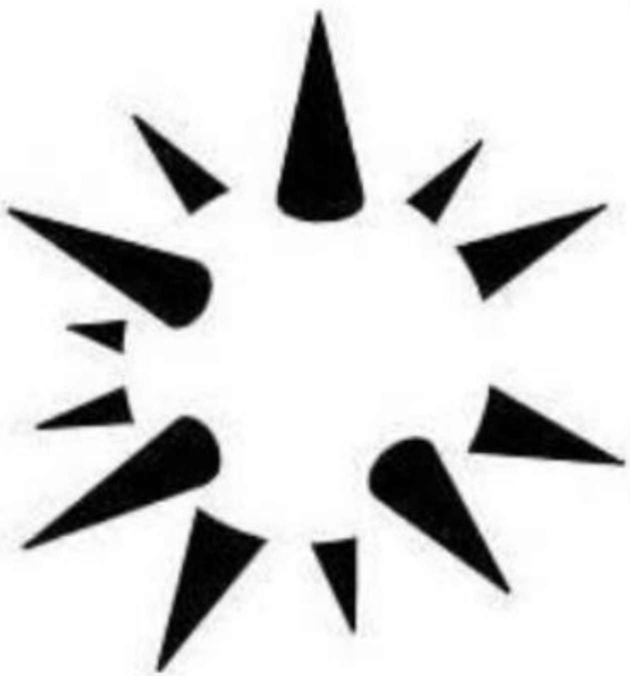
- addresses the process where humans usually first identify the whole and then the parts



Example of Emergence, where the dog can only be seen by looking at the image as a whole (source: thatbrandguy.com)

The principle of reification

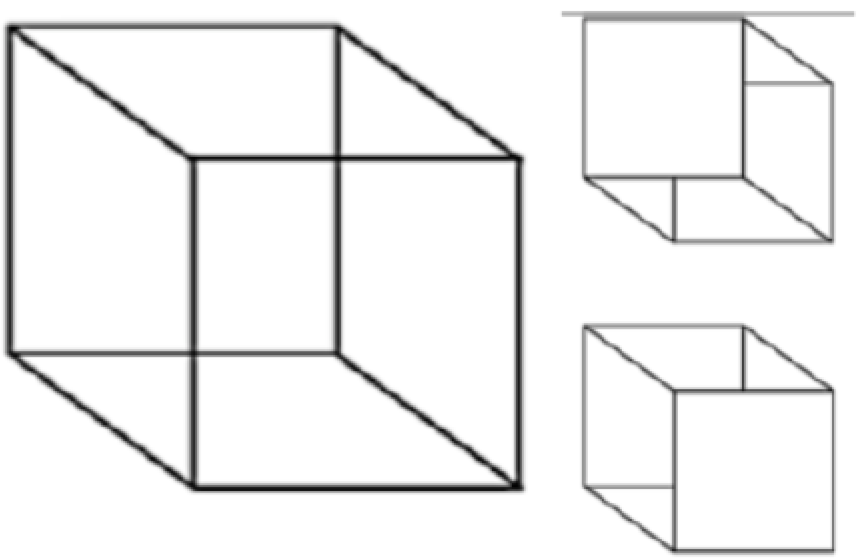
- addresses the aspect of perception in which the objects are perceived to have more spatial information than what is actually present; human perception seems to fill in the gaps.



Example of Reification, where a sphere can clearly be seen in the centre, even though there is none (source: study.com)

The principle of multi-stability

- describes the tendency of ambiguous perceptual experiences to switch between alternative interpretations, not being able to see two interpretations at once in an effort to avoid visual uncertainty.



Example of Multi-stability, where the cube can be seen in two ways (source: geoff-hart.com)

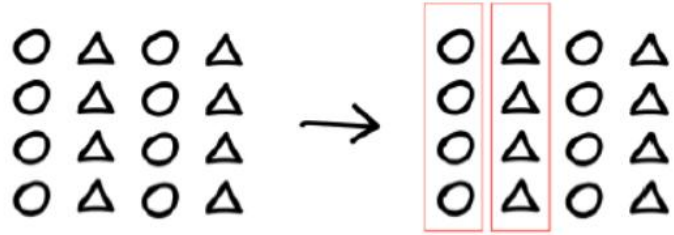
The principle of invariance

- addresses the fact that similar and different objects can be identified independent of the scale, rotation or translation.

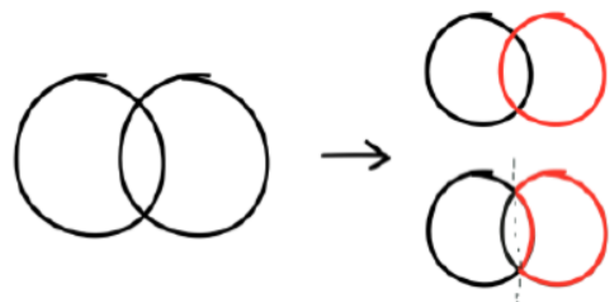
Example of Invariance, where similar objects can be identified even though the orientations are very different. (source: cns-alumni.bu.edu)

Laws of the gestalt psychology in relation to information visualization

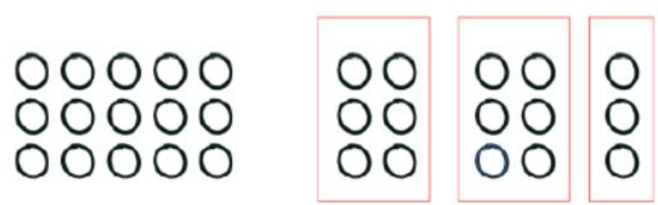
- Law of Similarity: Items that are similar are grouped together by the brain



- Law of Pragnanz: People will perceive and interpret ambiguous or complex images as the simplest form(s) possible.

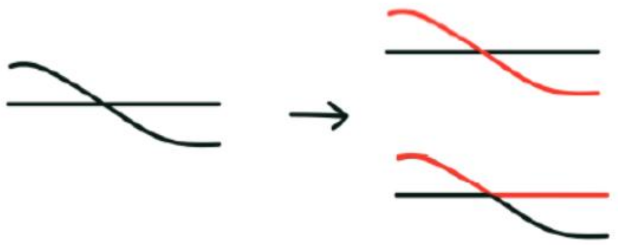


- Law of Proximity: objects that are close are grouped together



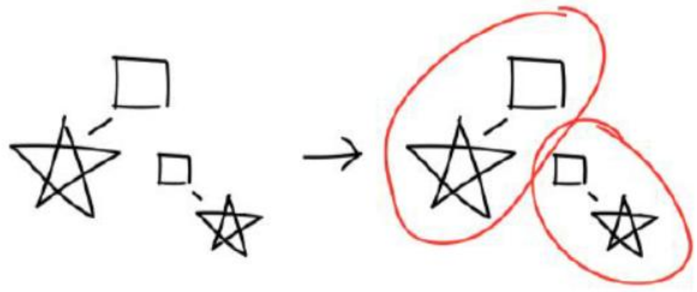
Laws of the gestalt psychology in relation to information visualization (cont.)

- Law of Continuity: lines are seen as following the smoothest path.



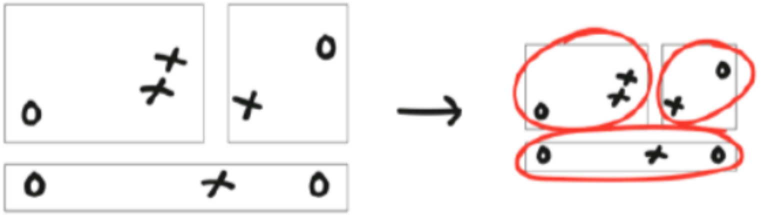
- Law of Closure: objects that are grouped together are seen as a whole, and the mind is filling the missing information.

- Law of uniform connectedness: items that are visually connected are perceived as more related.

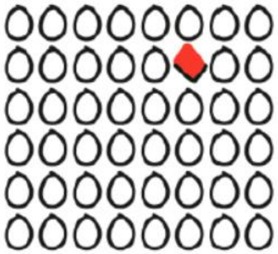


Laws of the gestalt psychology in relation to information visualization (cont.)

- Law of common regions: Elements that are located in the same closed region are perceived as part of a group.



- Law of focal points: Elements with a point of interest, emphasis or difference will capture and hold the viewer's attention.



- Law of past experiences: elements can be perceived according to an observer's past experience. Most of the times this is very subjective, but humans also have a lot of past experiences in common, as the familiar colours *red, orange and green from for example a traffic light.*.

Perception: visual variables

- Position
- Shape
- Size
- Bright
- Color
- Orientation
- Texture
- Movement

Perception: visual variables

- Position
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- Bright
- Color
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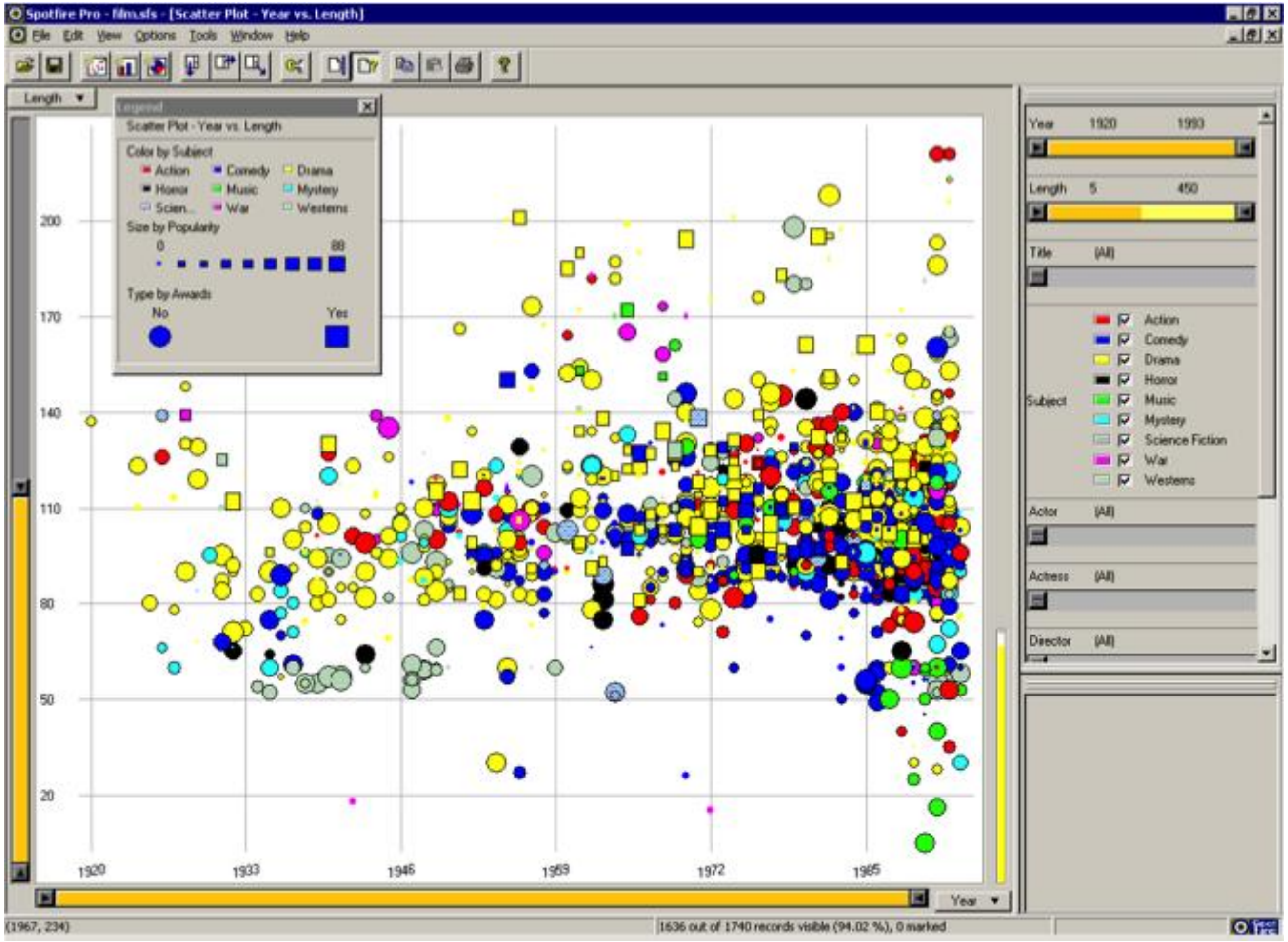
- Texture
- Movement



Perception: visual variables

- Position
- Shape
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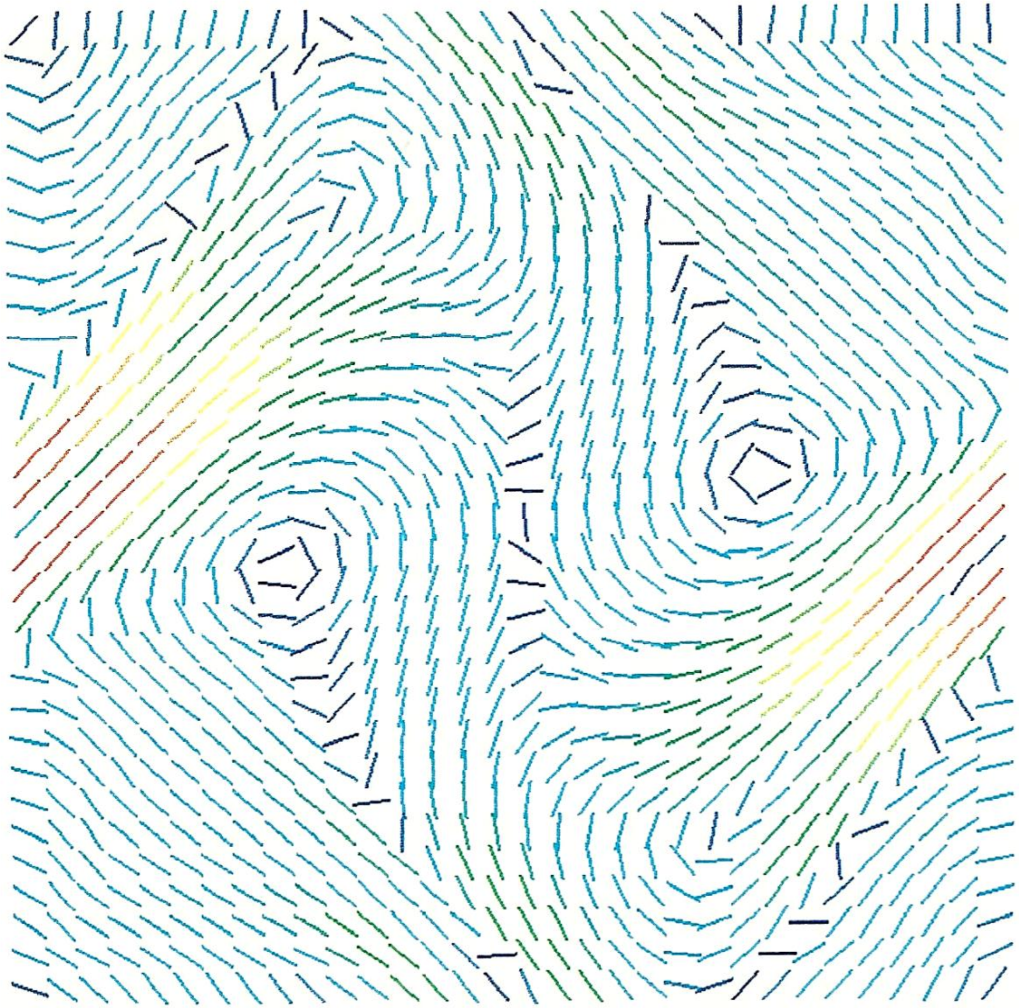
- Movement



Principles of data visualization

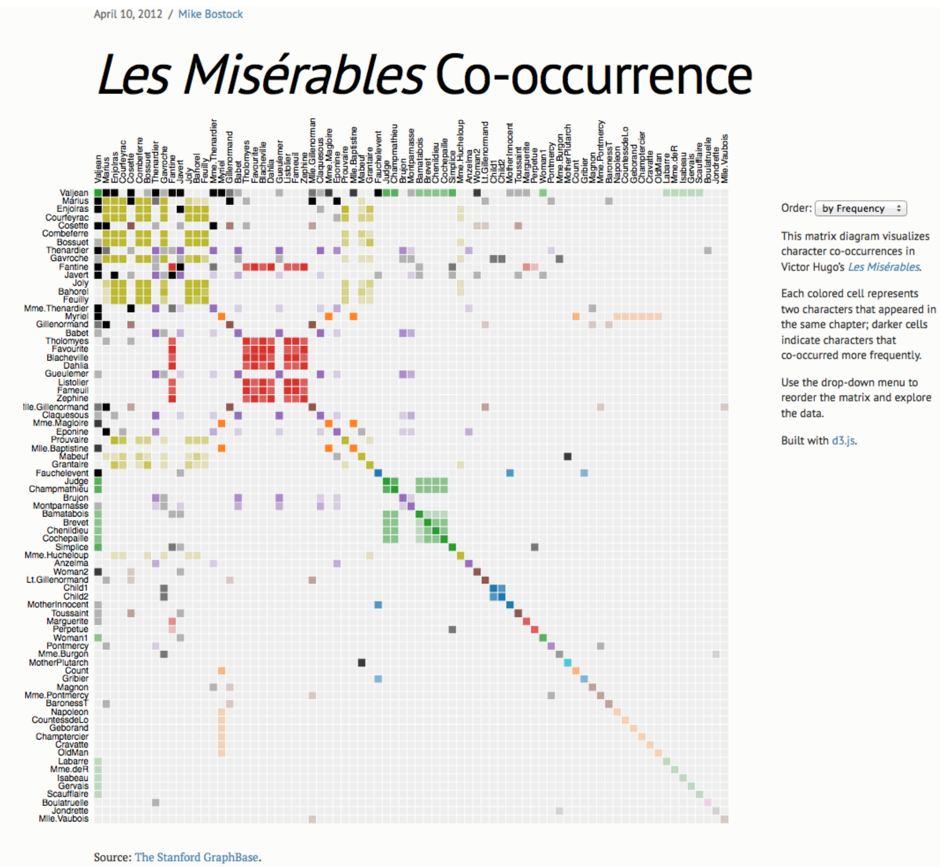
- Characterizing data
- User perception
- $\boxed{\text{Users task and interaction}}$

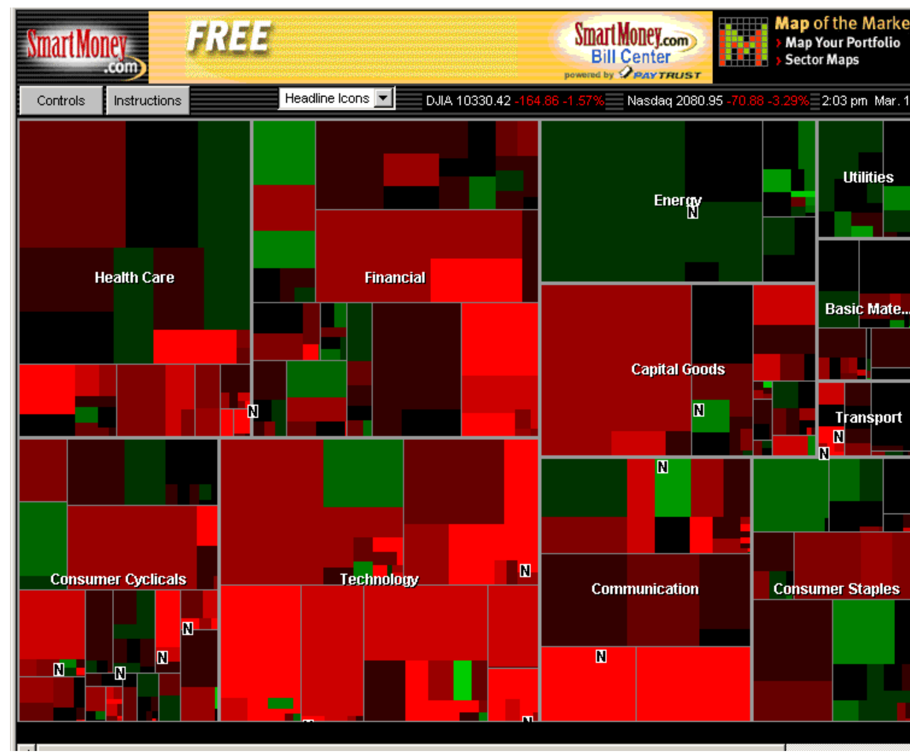
User interaction

- Changing the scene
  - Selection
  - Navigation
  - Reordering/reorganizing
  - Changing visual coding
- Latency
- Feedback
- Costs
  - Time and user attention

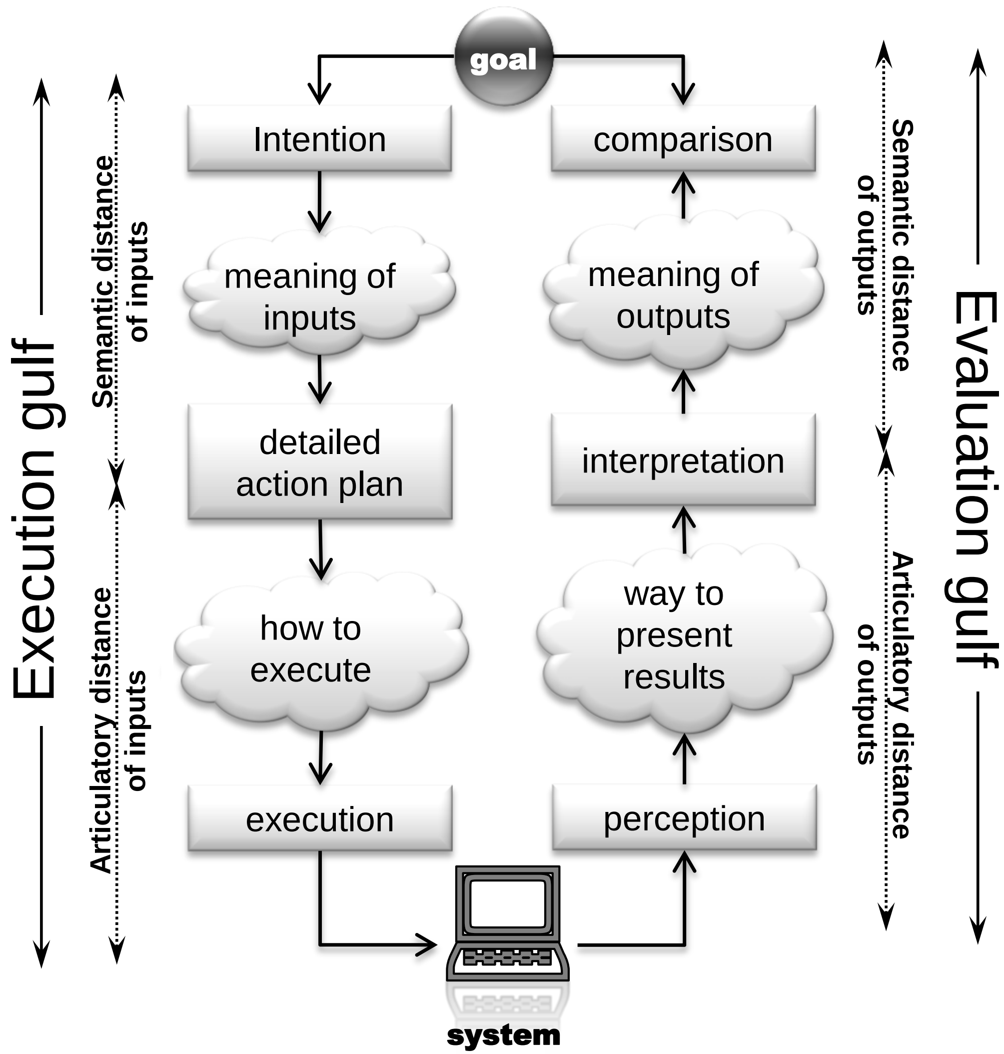
Exercise

- Identify the visual variables used in the following visualization technique





Interaction gulfs *(according to D. Norman, 1986)*



Execution gulf is the effort required for a user to express an intention in terms of commands or instructions

Evaluation gulf refers to the way the results provided by the system are meaningful or understandable by the users, and in accordance with their goals

User tasks (for visualization)

Keller e Keller (1994)

- Identify
- Locate
- Distinguish
- Categorize
- *Cluster*
- Order
- Compare
- Associate
- Correlate

Keller, P. e Keller, M. *Visual Cues: Practical Data Visualization*. IEEE Computer Society Press, 1994

Shneiderman (1996)

- **Overview**
- **“Zoom”**
- **Filter**
- **Details on demand**
- Relate
- History
- Export (data)

Shneiderman, Ben *The Eyes Have it: A Task by Data Type Taxonomy for Information Visualization*. 1996 IEEE Symposium on Visual Language, pp336-343

User tasks (for visualization)

- Wehrend and Lewis, 1990
- Springmeyer, 1990
- Shneiderman, 1996
- Zhou and Feiner, 1998
- Morse et al., 2000
- Amar and Stasko, 2004
- Amar et al., 2005
- Valiati et al., 2006

Low level analytical tasks

- Search value
- Filter dados
- Compute value
- Find limits
- Classify
- Determine range
- Characterize distribution
- Find annomalies
- *"Cluster"*
- Correlate

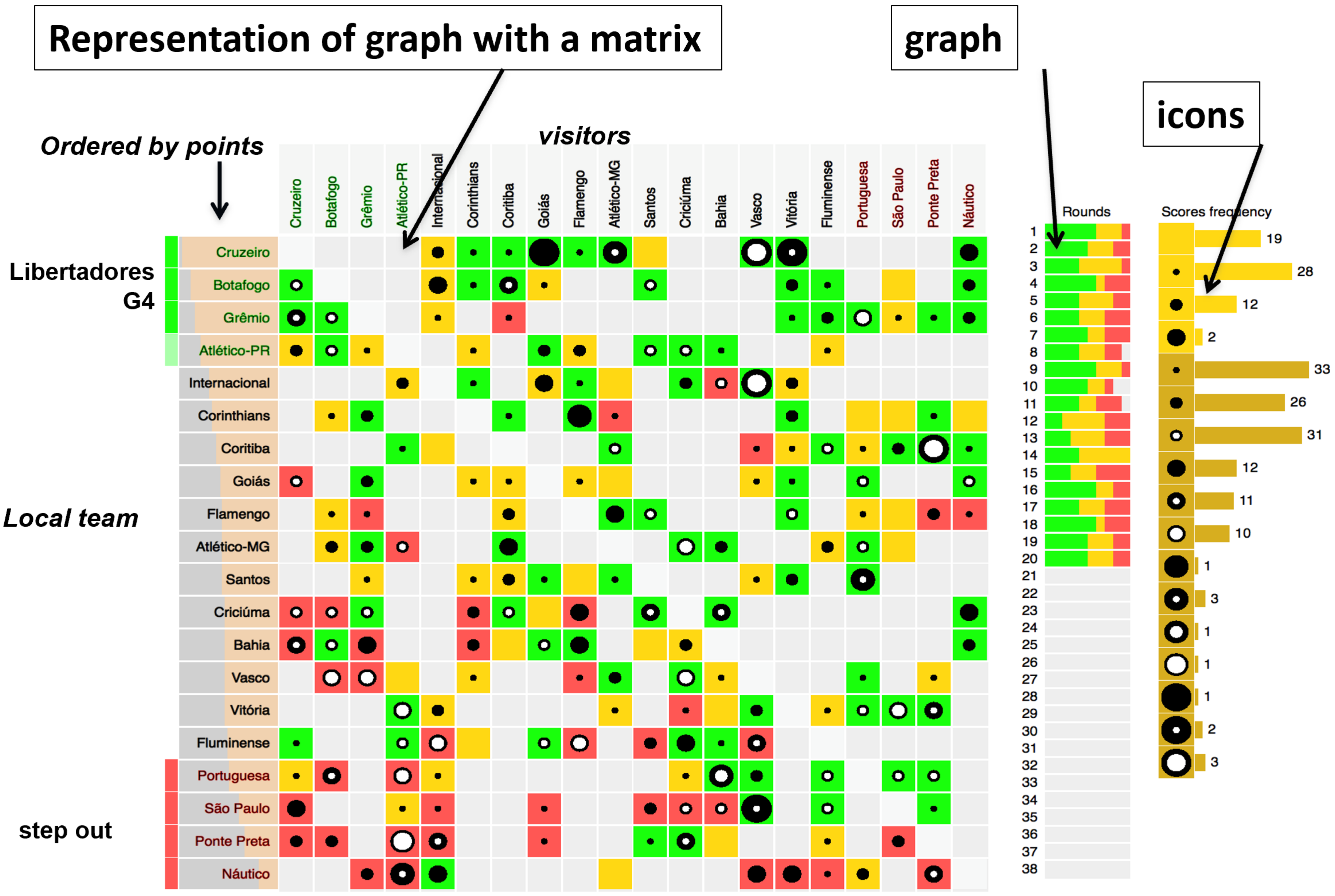
Exemple of techniques

Conclusion

- Many applications
  - Scientific ones (information processing, nature, social, …)
  - Application in industry (improving and monitoring processes)
  - Dedicated to specialized enterprise versus lay people
- Only recent recognition
- Recent expantion
  - 2005/2006 – Visual Analytics
    - Information visualization
    - Techniques for analyzing data

Exercise

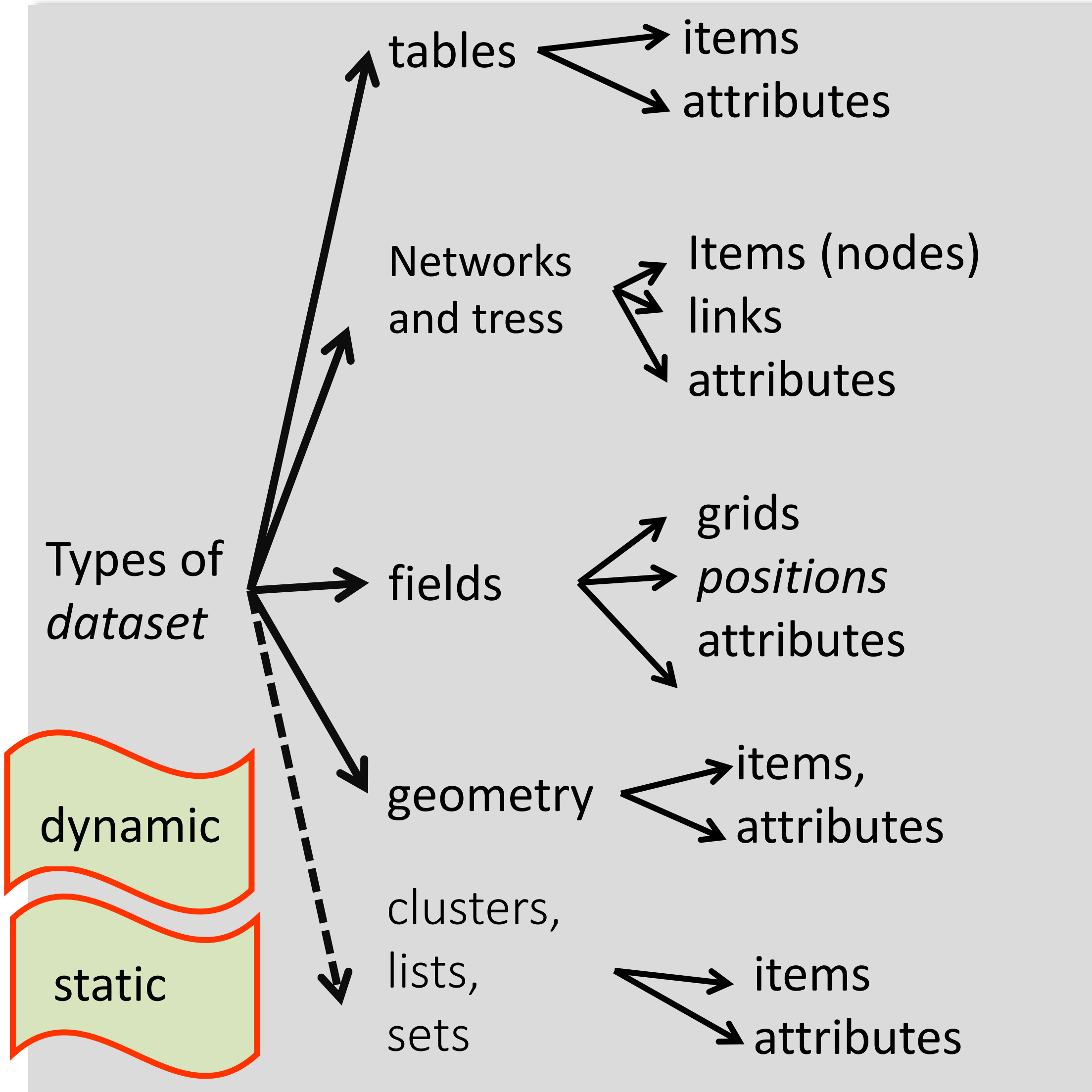
- Find the data set and classify it by identifying
  - Variable perceptive (ex. color, bright, etc)
  - Class of data
  - Nature and dimension of domain
  - Type of dataset and type of data



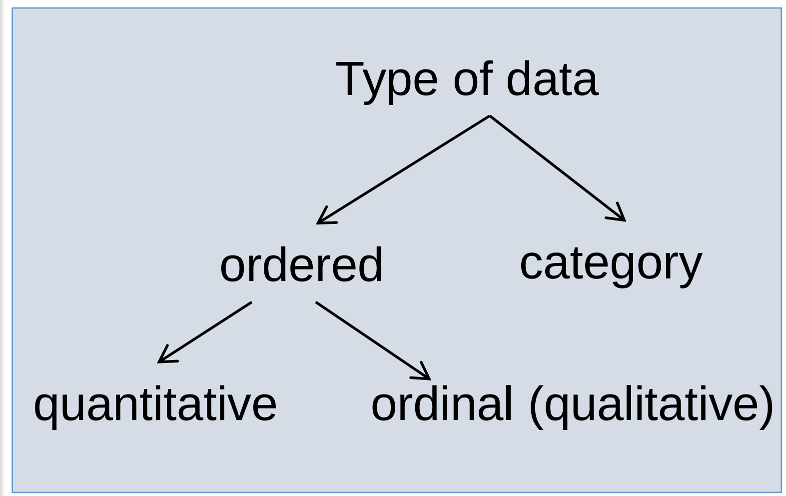
Representation of graph with a matrix
graph
icons
Ordered by points
visitors
Cruzeiro
Botafogo
Grêmio
Atlético-PR
Internacional
Corinthians
Coritiba
Goiás
Flamengo
Atlético-MG
Santos
Criciúma
Bahia
Vasco
Vitória
Fluminense
Portuguesa
São Paulo
Ponte Preta
Náutico
Libertadores G4
Local team
step out
Rounds
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
Scores frequency
19
28
12
2
33
26
31
12
11
10
1
3
1
1
1
2
3

Perception: visual variables

Type of data



- Position
- Shape
- Size
- Bright
- Color
- Orientation
- Texture
- Movement



Numeric, quantitative or ordered
Categories (items in a enumeration)

Munzner, Tamara *Visualization Analysis and Design*. Boca Raton, FL:Taylor & Francis, 2014

Project

Required tasks for the project

- Analyze data from a list of dataset from https://www.kaggle.com/
- Chose a dataset that contains multivariate data
- Validate the choice with supervisor (Aline or Marco)
- Describe the visualization pipeline allowing to create a visual representation of data (from row data to visual variables);
- Describe the target users;
- Describe the visualization goals and user tasks;
- Propose 1 visualization techniques using D3JS including by student:
  - Include interactive tasks (ex. navigation, selection, filters, etc.);
  - Include two levels of visualization (overview + details);
  - Allow to change the dataset;
  - Provide an executable demonstration;

Evaluation

- A report ~15 pages (max);
- A demo of the project;
- The source code of your project
- A written examination via Moodle;

Classifications of visualization techniques

- Types of visualization (examples for the project)
  - Hierarquie (ex. treemaps, sunburst)
  - Location (ex: Choropleth, map of dots)
  - Graph (ex. network, attributes on networks of edges and nodes)
  - Multiariate (ex. parallel coordinates, parallel set)

https://datavizcatalogue.com/