Interactive Information Visualization

How to make "a picture [. . .] worth a thousand words"

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Course objectives

After following this course, you will be able to:

- **know** the scientific foundations of InfoVis;
- **analyze** data sets using visualization techniques; and
- **build** visualization that convey information and ideas.

Planning

Only **four lectures** (4×1.5h), *i.e.*, a short introduction to the domain:

- Introduction, Human visual perception;
- The visualization pipeline, Data types, Seminal works;
- Trees and graph visualization; and
- Tabular data and time series, InfoVis toolkits.

Online ressources

Home page for the class:

`<http://mosig.imag.fr/ClassNotes/UIS-AHCI>`

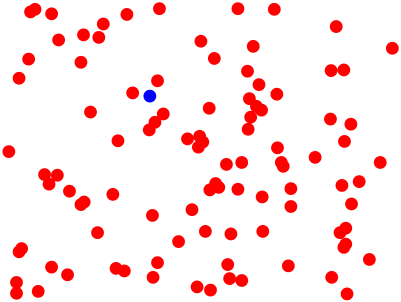
Problem

Q: What is the **best channel to convey information** to a human?
A: **Vision** because:

- **highest bandwidth** sense ($\approx 100\,\mathrm{MBs}^{-1}$, then ears $< 100\,\mathrm{bs}^{-1}$);
- **extends** memory and cognition;
- people **think visually**.

"Pre-attentive" perception

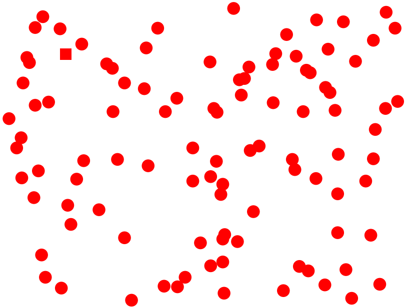
Find the **blue** dot. . .



. . . in **constant time**, no matter the number of red dots!

"Pre-attentive" perception (cont.)

Find the **square** dot. . .



. . . in **constant time**, no matter the number of circles!

Anscombe's Quartet (1973)

Four **data sets**:

I		II		III		IV	
x	y	x	y	x	y	x	y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.10	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.10	4	5.39	19	12.50
12	10.84	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

Anscombe's Quartet (1973) (cont.)

…having the exact **same statistical properties**:

- number of observations (n): 11
- mean of the x's ($\bar{x}$): 9.0
- mean of the y's ($\bar{y}$): 7.5
- equation of regression line: $y = 3 + 0.5x$
- sums of squares of $x - \bar{x}$: 110.0
- regression sums of squares: 27.50 (1 d.f.)
- residual sums of squares of y: 13.75 (9 d.f.)
- Multiple R^2: 0.667

Anscombe's Quartet (1973) (cont.)

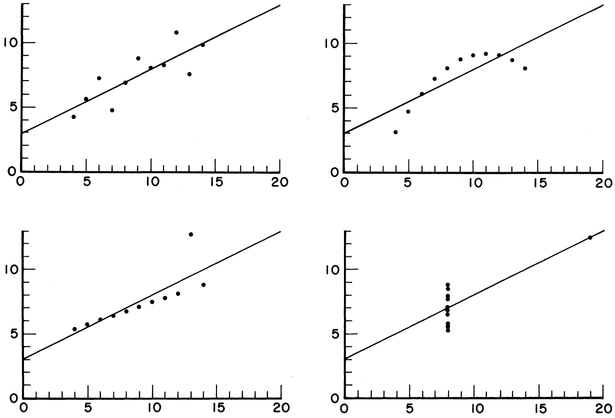


figure 1 : Anscombe's quartet plotted.

Visual thinking

"A picture is worth a thousand words"
— *anonymous, 1911*

"Un petit dessin vaut mieux qu'un long discours"
— *Napoléon Bonaparte, 18xx*

Visual thinking (cont.)

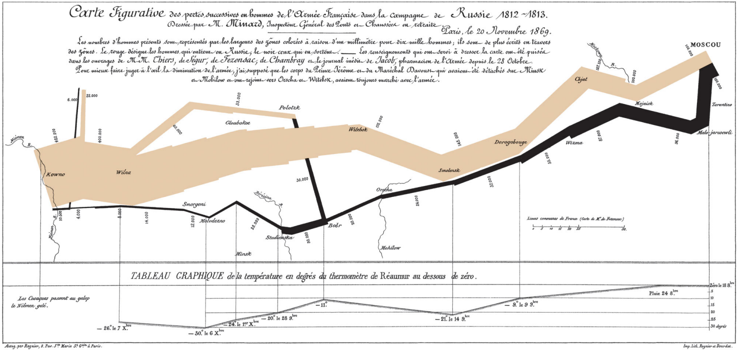


figure 2 : Charles Minard's 1869 chart showing the number of men in Napoleon's 1812 Russian campaign army, their movements, as well as the temperature they encountered on the return path.

Communication

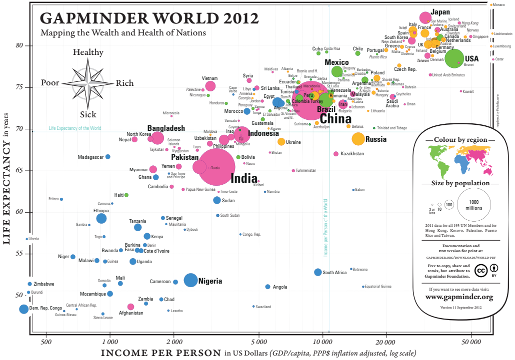


figure 3 : Hans Rosling's <Gapminder world>.

Information Visualization

InfoVis

*"The use of **computer-supported, interactive visual representations** of data to **amplify cognition**"*
— Card, Mackinlay & Shneiderman, 1998

Many fields are involved:

- **graphics** (millenniums of history)
- **cognitive psychology** (centuries of history)
- **Human-computer interaction** (decades of history)

Scientific Visualization

SciViz

Visualization of data sets captured from real world, having a **given spatialization.**

Key differences:

- continuous math vs. discrete math
- limited set of application domains
- smaller design space

Challenges

- **scale**: what is a *large* dataset?
- **diversity**: what is *information*?

Simplified model

Visual perception is a **two stage process**:

- a **parallel** extraction of **low-level** properties; then
- a **sequential goal-directed** processing.

Pre-attentive processing

Parallel processing by the retina (bottom-up) of:

- orientation;
- color;
- texture;
- movement;
- etc.

Pre-attentive processing (cont.)

The **Feature-Integration Theory of Attention** [Treisman & Gelade, 1980] can be seen as a **limit case** of **Visual Search and Attention: a Signal Detection Theory Approach** [Verghese, 2001].

- A. Treisman and G. Gelade. A Feature-Integration Theory of Attention. In Cog. Psycho., vol. 12, 97–136, 1980.
- Preeti Verghese. Visual Search and Attention: a Signal Detection Theory Approach. In Neuron, vol. 31, 523–535, 2001.

Goal-directed processing

Sequential processing by upper level in the brain (top-down):

- object segmentation;
- object identification;
- etc.

Eye anatomy

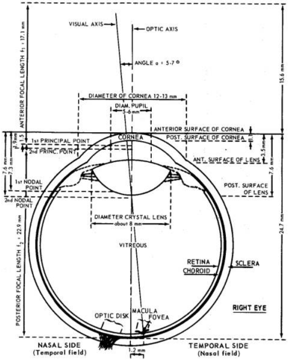


figure 4 : Right eye.

Acuity

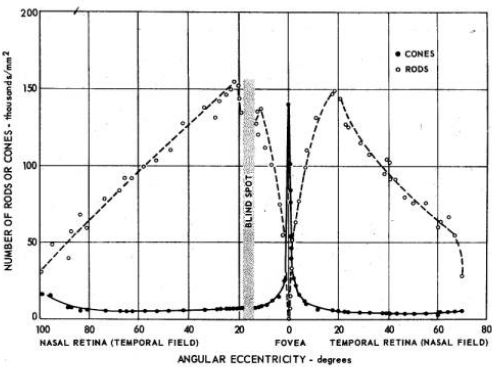


figure 5 : Density of receptors.

Visual field

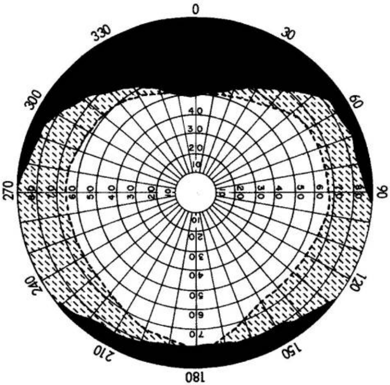


figure 6 : Binocular visual field.

Summary

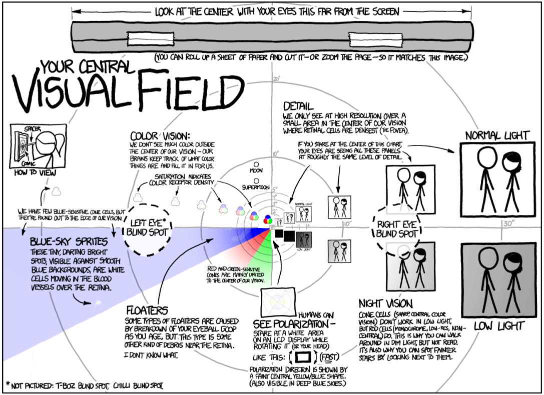


figure 7 : Your central visual field `<http://xkcd.com/1080/>`.

Gestalt psychology (192X)

figure 8 : "My wife and my mother-in-law." (1915)

Gestalt psychology (192X) (cont.)

The *Gestalt* psychology is a **theory of perception** that is often summed up by:

> *"The whole is other than the sum of the parts"*
>
> — *Kurt Koffka (1922)*

Gestalt psychology (192X) (cont.)

The *Gestalt* psychology notably describes the **perception of forms** by the visual system. It relies on four principles:

- **Emergence**;
- **Reification**;
- **Multistability**; and
- **Invariance**.

It also describes our visual perceptions by a **set of laws**.

Emergence

figure 9 : emergence

Emergence (cont.)

Emergence

The **global perception** can **not** be **explained by** the sum of **its parts**.

Reification

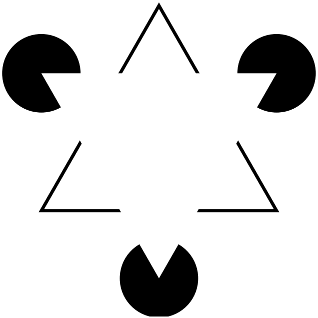


figure 10 : reification

Reification (cont.)

Reification

The **perception** contains **more** spatial **information that the stimulus** on which it is based: part of the perception is generated.

Multistability

figure 11 : multistability

Multistability (cont.)

Multistability

Ambiguous stimuli can generate different perceptions but they can not coexist simultaneously.

Invariance

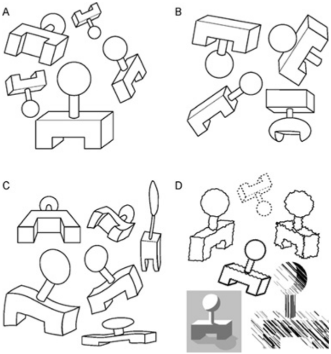


figure 12 : invariance

Invariance (cont.)

Invariance

Objects are recognized independently of various variations, such as geometrical transformations, lighting, etc.

Gestalt laws of grouping

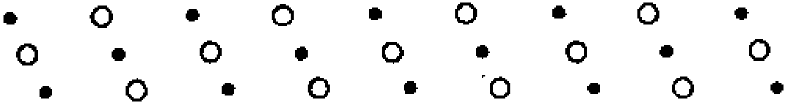


figure 13 : grouping of dots (illustration from <`Laws of Organization in Perceptual Forms (1923)`>).

The **laws of grouping** state how **low-level perceptions** are grouped **into higher-level objects**.

Gestalt laws of grouping (cont.)

Good *Gestalt* (*Prägnanz*)

We tend to order our experience in a manner that is regular, orderly, symmetric, and simple.

Proximity

Objects that are close tend to be perceived as a group.

Similarity

Objects that are similar (in shape, color, shading, etc.) tend to form a group.

Closure

The perception fills gaps in stimuli.

Gestalt laws of grouping (cont.)

Symmetry

Objects with symmetric disposition tend to be perceived as forming a whole.

Common Fate

Objects evolving together are perceived as a group.

Continuity

Ambiguous stimuli are perceived preferentially with the interpretation that is the most continuous.

Past Experience

We group things we have learned to group (e.g. letters in cursive writing)

The Visual Information-Seeking Mantra

The **Visual Information-Seeking Mantra** [Shneiderman, 1996]:

- **Overview first**,
- **Zoom and filter**, then
- **Details-on-demand.**

- Ben Shneiderman. The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. In Proc. Visual Languages, 336–343, 1996.

The Information Visualization Pipeline

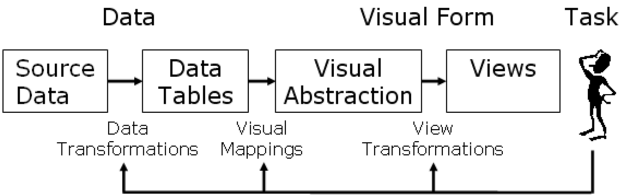


figure 14 : InfoVis pipeline [Chi & Riedl, 1998].

- E. Chi and J. Riedl. An Operator Interaction Framework for Visualization Systems. In proc. InfoVis'98, 63–70, 1998.

Data

Several taxonomies of **data types**, e.g., [Card & Mackinlay, 1997]:

- **Nominal** (identity)
- **Ordered** (comparison)
- **Quantitative** (differences, ratios)

- S. Card and J. Mackinlay. The Structure of the Information Visualization Design Space. In proc. InfoVis'97, 92–99, 1997.

Graphic variables

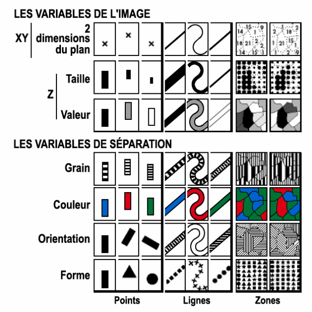


figure 15 : Graphic variables [Bertin, 1967].

- Jacques Bertin. Sémiologie graphique. 1967.

A note on color

Color is a 3D space, with different parametrizations.
The **color opponent process model** [Ware, 2000] is the most "psychophysical":

- **black-white** (luminance $=$ red $+$ green)
- **red-green**
- **yellow-blue** (luminance $-$ blue)

- C. Ware. Information visualization. 2000.

Guidelines for mapping

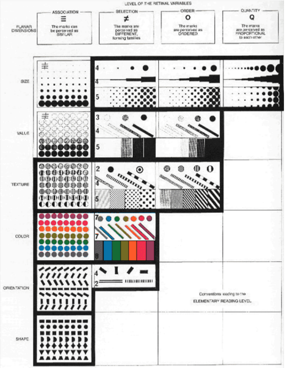


figure 16 : Variable properties [Bertin, 1967].

Guidelines for mapping (cont.)

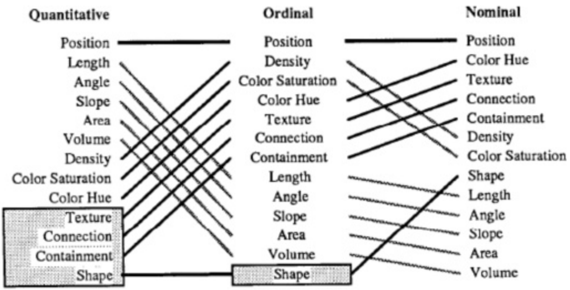
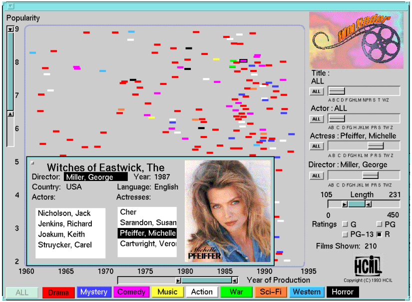


figure 17 : Suitability of variables [Mackinlay, 1986].

- J. Mackinlay. Automating the Design of Graphical Presentations of Relational Information. ACM Trans. Graph. 5(2): 110–141, 1986.

Design space for mapping



Name	D	F	D'	X	Y	Z	T	R	—	[]	CP
Year	Q	>	Q	P							
Quality	Q	>	Q		P						
Type	N	>	N					C			
Title	O	sl>									
Actor	O	sl>									
Actress	O	sl>									
Director	O	sl>									
Length	Q	br>									
Rating	N	br>									

figure 18 : Characterization of Film finder [Card & Mackinlay, 1997].

Taxonomy of networks

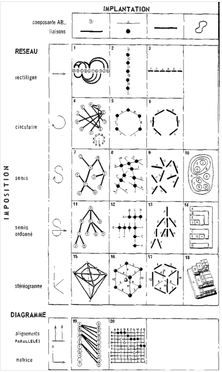


figure 19 : Taxonomy of networks [Bertin, 1967].

A tour through the visualization zoo

Let's take a `<tour through the Visualization zoo>` [Heer et al., 2010]!

- J. Heer, M. Bostock, V. Ogievetsky. A Tour Through the Visualization Zoo. Communications of the ACM 53(6): 59–67, 2010.

A tour through the visualization zoo (cont.)

Some other zoos:

- a `<tree visualization reference>` [Schulz, 2011];
- a `<visual survey of visualization techniques for time-oriented data>` [Aigner et al., 2011];
- a `<survey of text visualization techniques>`; and

- H. Schulz. Treevis.net: a Tree Visualization Reference. IEEE Computer Graphics and Applications 31(6): 11–15, 2011.
- W. Aigner, S. Miksch, H. Schumann, C. Tominski. Visualization of Time-Oriented Data. 2011.

A tour through the visualization zoo (cont.)

And some more zoos:

- a <survey on multifaceted scientific data visualisation> [Kehrer & Hauser, 2013];
- a <review of temporal visualizations based on space-time cube operations> [Bach et al., 2014];

- J. Kehrer, H. Hauser.
  Visualization and Visual Analysis of Multifaceted Scientific Data: a Survey.
  IEEE Transactions on Visualization and Computer Graphics 19(3): 495–513, 2013.
- B. Bach, P. Dragicevic, D. Archambault, C. Hurter, S. Carpendale.
  A Review of Temporal Data Visualizations Based on Space-Time Cube Operations.
  In proc. EuroVis'14, State of The Art Reports.
  .

A tour through the visualization zoo (cont.)

And even more zoos:

- a `<survey on set visualization>` [Alsallakh et al., 2014];
- a `<state of the art in visualizing dynamic graphs>` [Beck et al., 2014].

- B. Alsallakh, L. Micallef, W. Aigner, H. Hauser, S. Miksch, P. Rodgers. Visualizing Sets and Set-typed Data: State-of-the-Art and Future Challenges. In proc. EuroVis'14, State of The Art Reports.
.
- F. Beck, M. Burch, S. Diehl, D. Weiskopf. The State of the Art in Visualizing Dynamic Graphs. In proc. EuroVis'14, State of The Art Reports.
.

The Information Visualization Pipeline (bis)

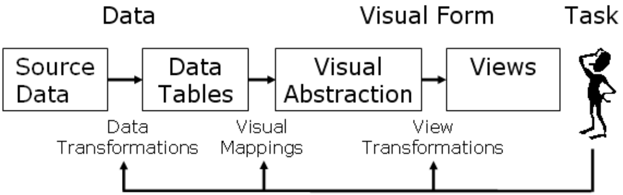


figure 20 : InfoVis pipeline [Chi & Riedl, 1998].

Multi-variate data

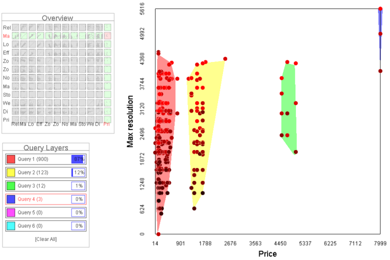


figure 21 : `<ScatterDice> [avi]` [Elmqvist et al., 2008].

- N. Elmqvist, P. Dragicevic, J.-D. Fekete. Rolling the Dice: Multidimensional Visual Exploration using Scatterplot Matrix Navigation.
  In Proc. InfoVis 2008, 1141-1148, 2008.

Zoomable treemaps

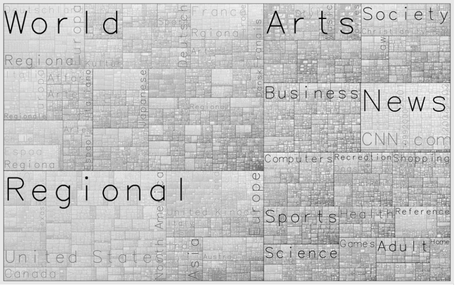


figure 22 : `<Zoomable Treemaps> [mov]` [Blanch & Lecolinet, 2007].

- R. Blanch and É. Lecolinet. Browsing Zoomable Treemaps: Structure-Aware Multi-Scale Navigation Techniques. In Proc. of InfoVis 2007, 1248–1253, 2007.

Alternate visualization of graphs

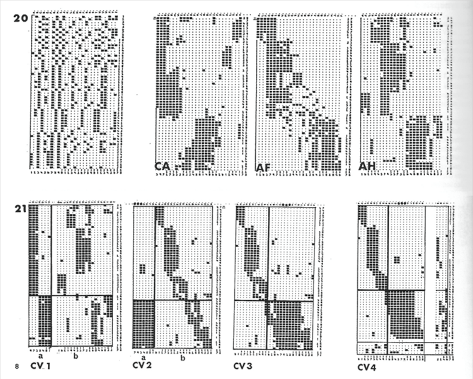


figure 23 : Reorderable matrices [Bertin, 1967].

Hybrid visualization of graphs

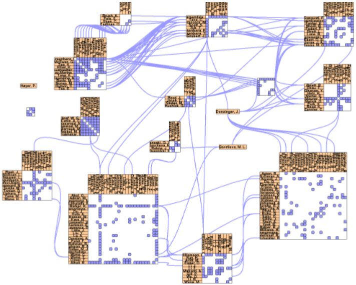


figure 24 : `<NodeTrix> [mov]` [Henry et al., 2007].

- N. Henry, J.-D. Fekete, M. J. McGuffin. NodeTrix: A Hybrid Visualization of Social Networks. In Proc. of InfoVis 2007, 1302-1309, 2007.

Hybrid tree/matrix visualizations

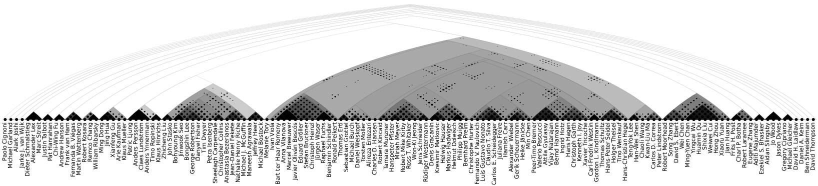


figure 25 : Dendrogramix [Blanch et al., 201X].

- R. Blanch, R. Dautriche and G. Bisson. Dendrogramix: a Hybrid Tree-Matrix Visualization Technique to Support Interactive Exploration of Dendrograms. work in progress.

Thank you!

Thank you for your attention!