
Scientific Information and
Data Visualization
to Friedman (2008) the "main goal of data
on is to communicate information clearly and effectively through
neans. It doesn' t mean that data visualization
ook boring to be functional or extremely sophisticated to look
To convey ideas effectively
ality need to go hand in
parse and complex data se
spects in a more intuitive way. Yet designers often fail to achieve
lance between form and function, creating go
which fail to serve their main purpose — to
communicate information".[2] Indeed, Fernanda V
ave suggested that an ideal visualization
not merely communicate clearly, but stimulate viewer engagement and att

Course Info.

- http://cc.sjtu.edu.cn/visualization.html

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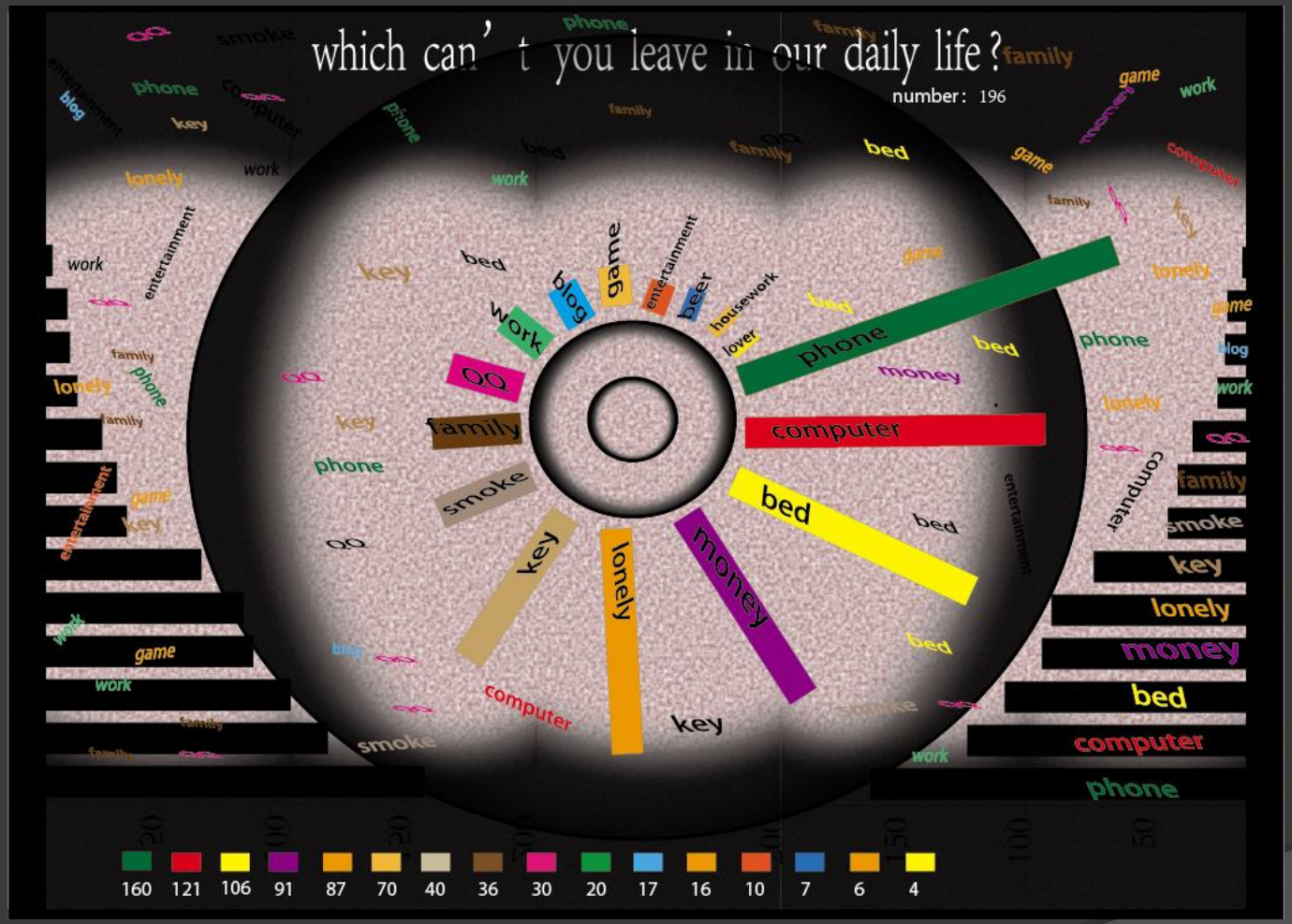
Books

* Alexandru C. Telea, ***Data Visualization – Principles & Practice,*** A K Peters, 2008.
- Markus Hadwiger et al., ***Real-Time Volume Graphics,*** A K Peters 2006.
- C.D. Hansen, C.R. Johnson (eds.), ***The Visualization Handbook***, Academic Press, 2004.
- B. Lichtenbelt, B., R. Crane, S. Naqvi, ***Introduction to Volume Rendering***, Prentice Hall PTR, Upper Saddle River, NJ, 1998.
- W.J. Schroeder, K. Martin, W. Lorensen, ***The Visualization Toolkit - An Object-Oriented Approach to 3D Graphics***, Kitware Inc., 3rd. ed. 2003.
- R. Spence, ***Information Visualization***, ACM Press /Addison Wesley, 2001.

Data Visualization

1. **Basic Concept: Data Visualization**
2. **Visualization pipeline**
3. **Data representations**
4. **Volume(scalar) visualization**:
   -- surface extraction, direct volume rendering
5. **Vector field visualization**
6. **Information Visualization**

Visualization



A Picture Is Worth a Thousand Words

Visualization

Visualization is a cognitive process performed by humans in forming a mental image of a domain space

Human Cognition

Visualization

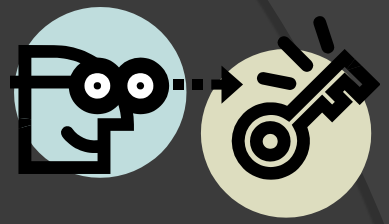
Visualization is a visual representation of a domain space using graphics, images, animated sequences, and sound augmentation to present data, structure, and dynamic behavior of large, complex data set that represent systems, events, processes, objects, and concepts [Williams et al. 1995]

At Information Age

Related fields

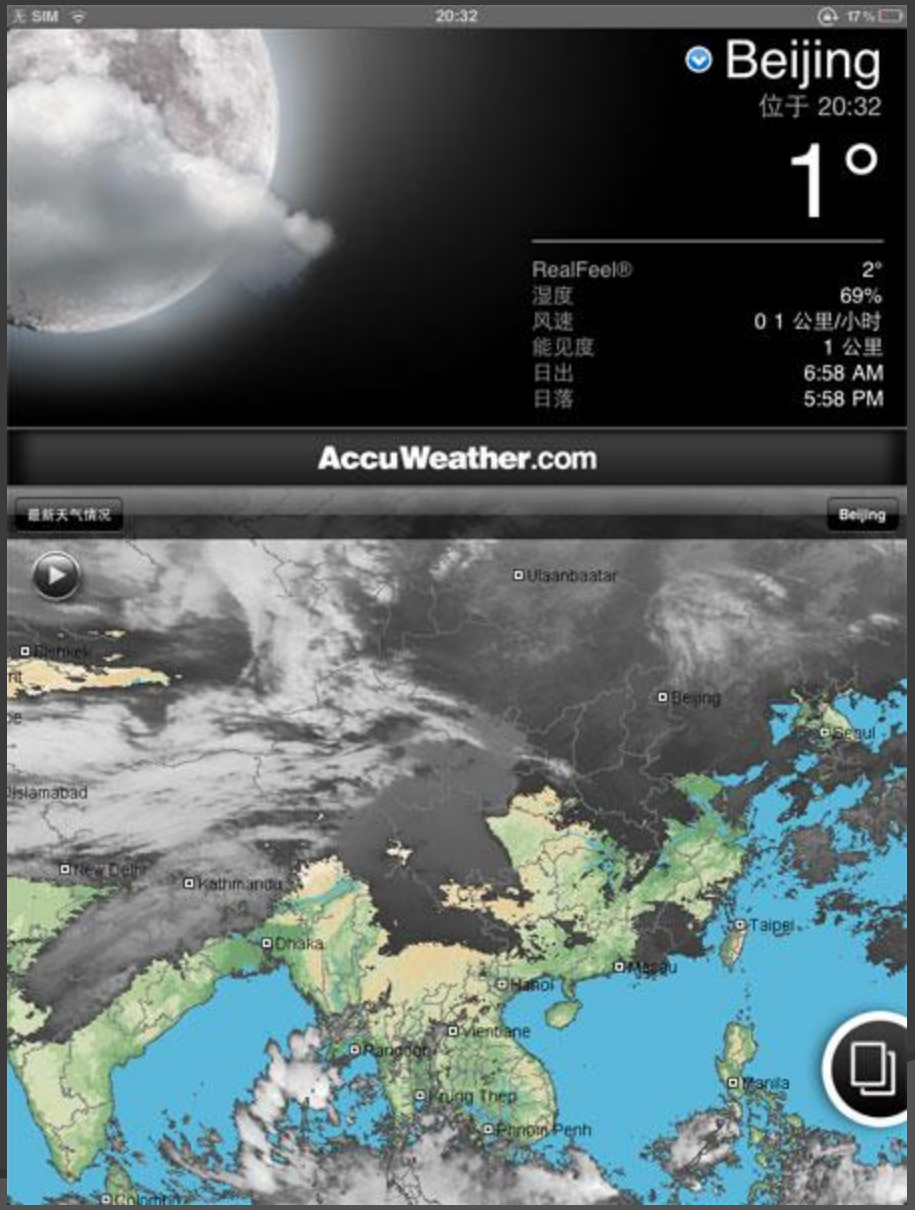
- Computer Graphics
- Data analysis
- Data mining
- Database
- Human–computer interaction (HCI)
- Infographics

For Sciences

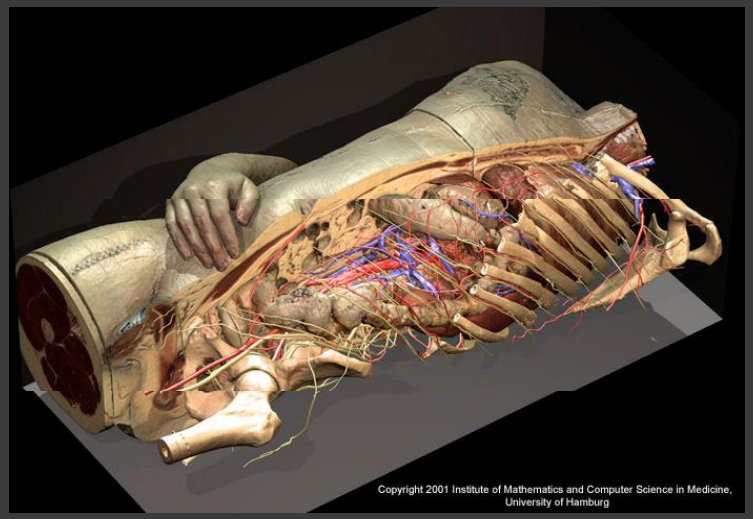


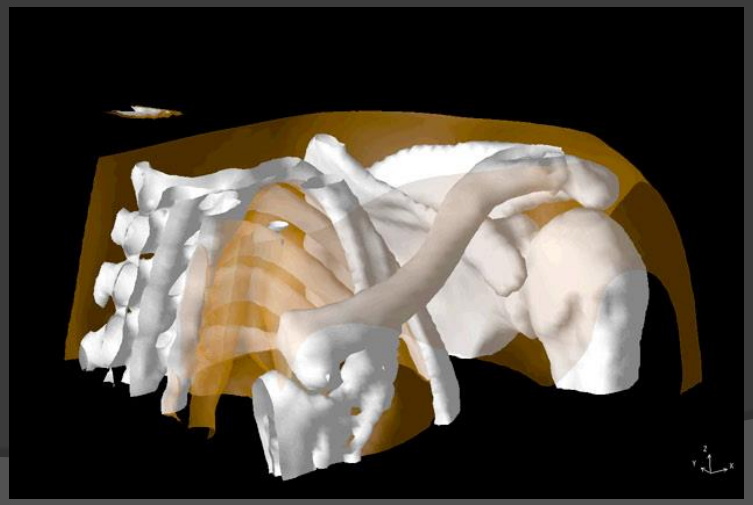
- Effective communication
- Provide scientific insights
- Make scientific discoveries

Examples: climatology

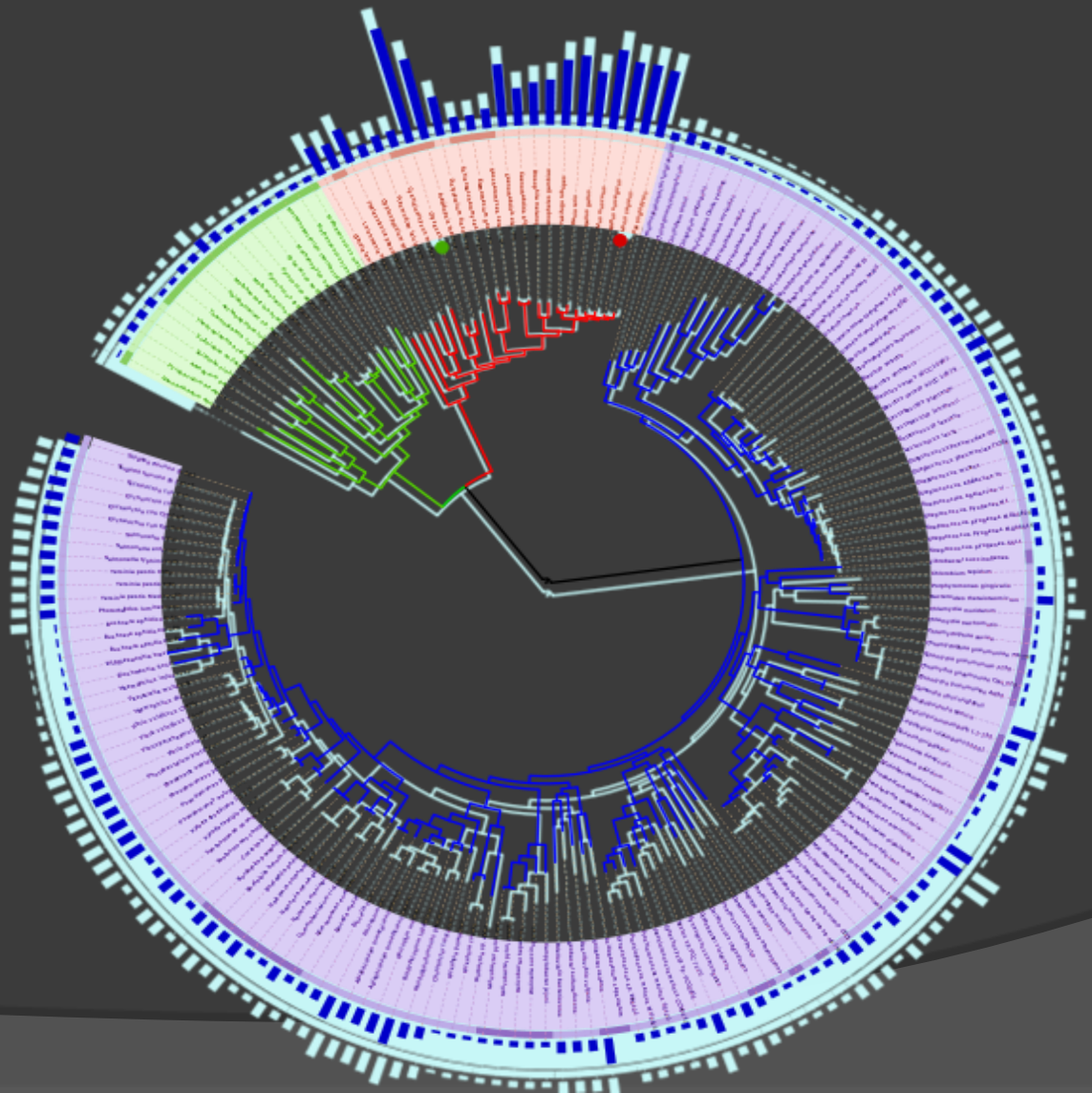


Examples: biomedical visualization





Examples: genetics

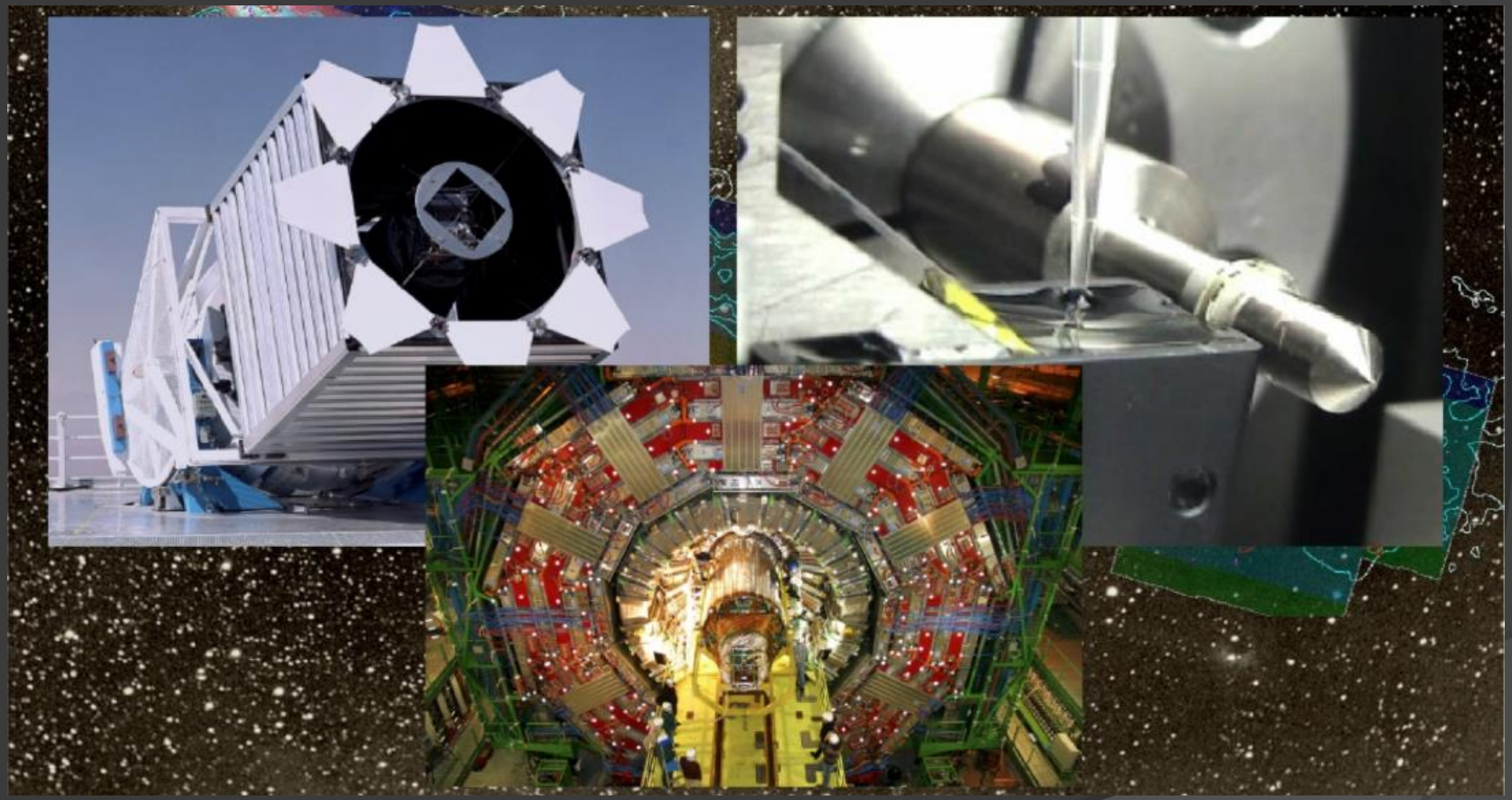


Tree of life with genome size

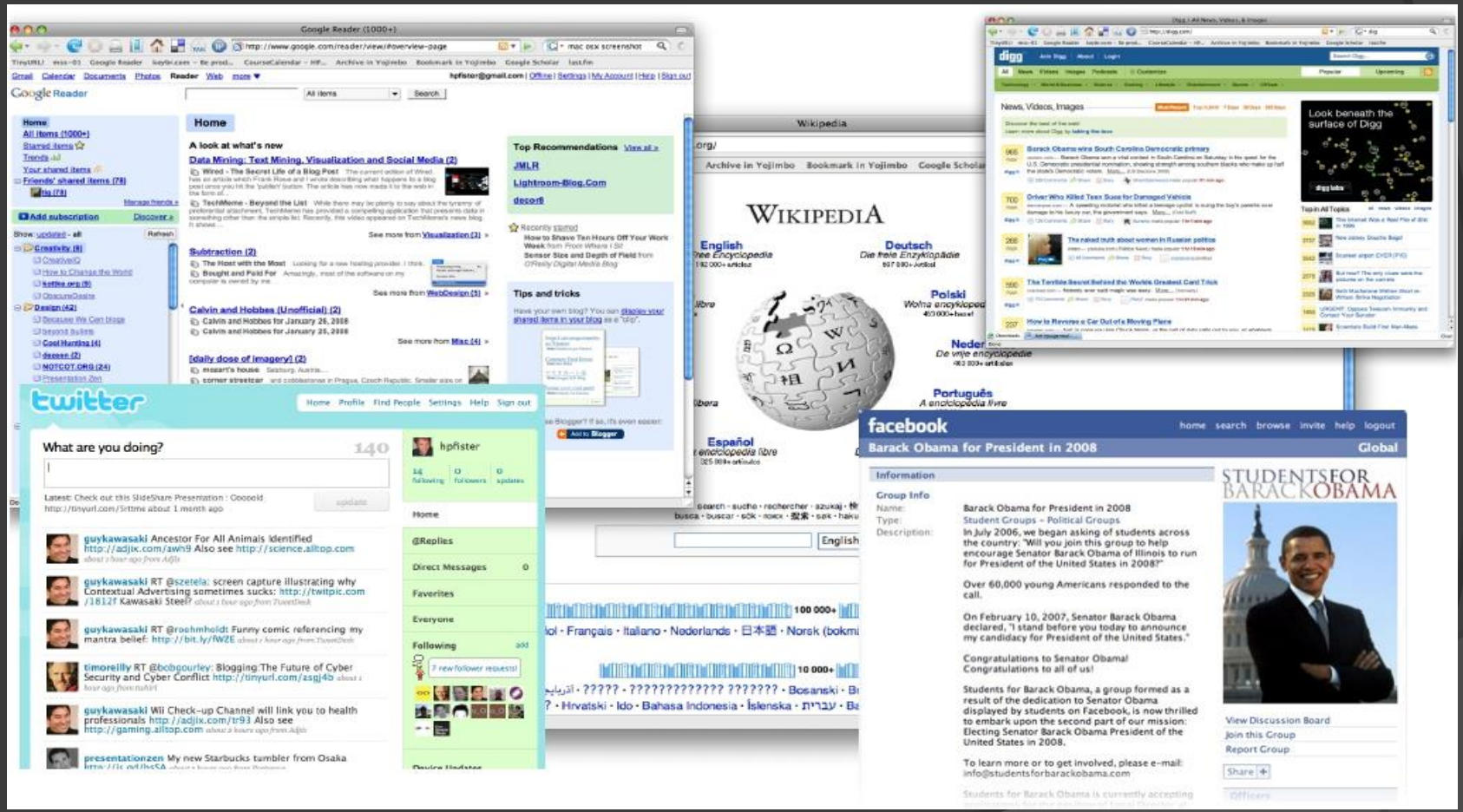
Why we need visualization?

- Larger data production by acquisition and simulation →better data consumption needed
  - medical imaging (CT etc)
  - seismic/geological data (Petroleum Exp., Earthquake inv.)
  - wind tunnel simulation (air dynamics, airspace indu.)
  - meteorological data (weatherforecasting …)

Scientific Big Data



Information Explosion



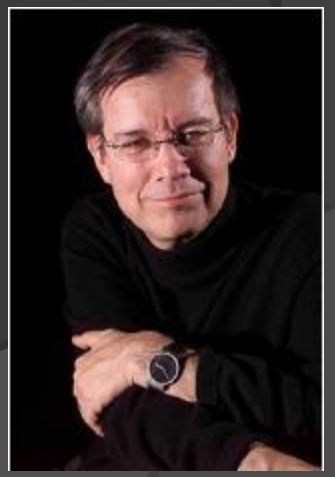
- “The ability to take data—to be able to **understand** it, to **process** it, to **extract value** from it, to **visualize** it, to **communicate** it —that’s going to be a hugely important skill in the next decades,... because now we really do have essentially free and ubiquitous data.”
  - - HalVarian, Google’s Chief Economist
    The McKinsey Quarterly, Jan 2009

Why we need visualization?

- Visualization can
  - Help thinking
  - Use perception instead of cognition
  - Work as external auxiliary of working memory
  - Enhance cognitive abilities

- “Visualization is really about external cognition, that is, how resources outside the mind can be used to boost the cognitive capabilities of the mind.”

Stuart Card



Which kind of information extracted?

- **Quantitative message**

  minimum/maximum values, …
- **Qualitative message**

  certain features/pattern: oil in geological data; tumor in medical imaging ...
- **Analysis/curiosity**

--- ranging from precise to fully vague

These graphics are supposed to convey information more clearly and more effectively than text.

- Most are designed to inform, but some are also supposed to be persuasive. For this assignment, examine each of these graphics and answer the questions in your memo.
- A**lso Consider:**
  - Is the graphic an effective way of communicating information?
  - What do you think is the main point made by each graphs?
  - Do you have both an intellectual and an emotional response to these graphics? If so, what are they?

Data => Graphics / Images

9.5012929e-01	4.9655245e-01	1.2104711e-01	2.9740568e-01
2.3113851e-01	8.9976918e-01	4.5075394e-01	4.9162489e-02
6.0684258e-01	8.2162916e-01	7.1588295e-01	6.9318045e-01
4.8598247e-01	6.4491038e-01	8.9284161e-01	6.5010641e-01
8.9129897e-01	8.1797434e-01	2.7310247e-01	9.8298778e-01
7.6209683e-01	6.6022756e-01	2.5476930e-01	5.5267324e-01
4.5646767e-01	3.4197062e-01	8.6560348e-01	4.0007352e-01
1.8503643e-02	2.8972590e-01	2.3235037e-01	1.9878852e-01
8.2140716e-01	3.4119357e-01	8.0487174e-01	6.2520102e-01
4.4470336e-01	5.3407902e-01	9.0839754e-01	7.3336280e-01
6.1543235e-01	7.2711322e-01	2.3189432e-01	3.7588548e-01
7.9193704e-01	3.0929016e-01	2.3931256e-01	9.8764629e-03
9.2181297e-01	8.3849604e-01	4.9754484e-02	4.1985781e-01
1.7626614e-01	3.7041356e-01	6.4081541e-01	7.9387177e-01
4.0570621e-01	7.0273991e-01	1.9088657e-01	9.1995721e-01
9.3546970e-01	5.4657115e-01	8.4386950e-01	8.4472150e-01
9.1690444e-01	4.4488020e-01	1.7390025e-01	3.6775288e-01
4.1027021e-01	6.9456724e-01	1.7079281e-01	6.2080133e-01
8.9364953e-01	6.2131013e-01	9.9429549e-01	7.3127726e-01
5.7891305e-02	7.9482108e-01	4.3979086e-01	1.9389318e-01
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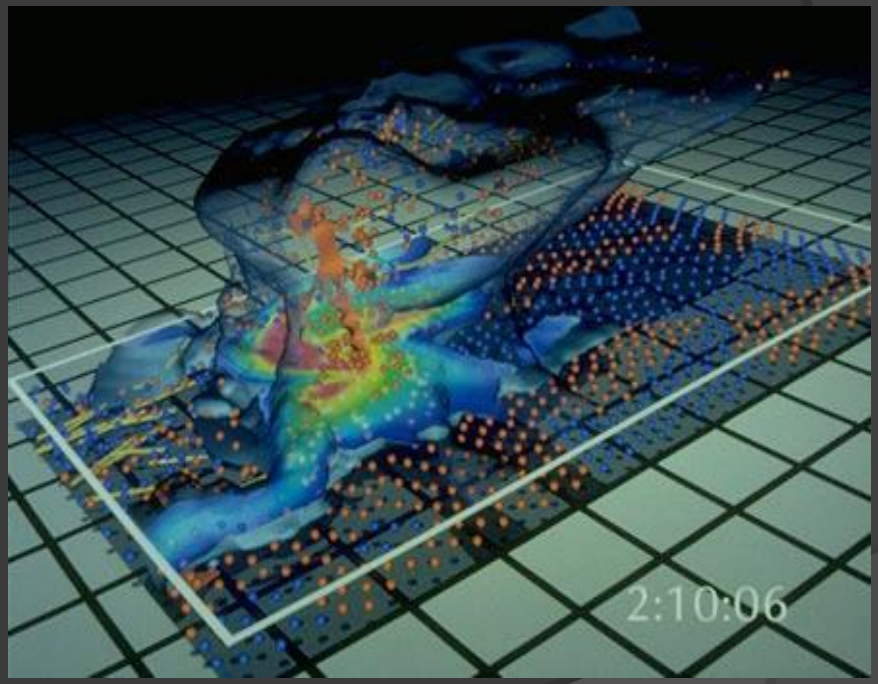
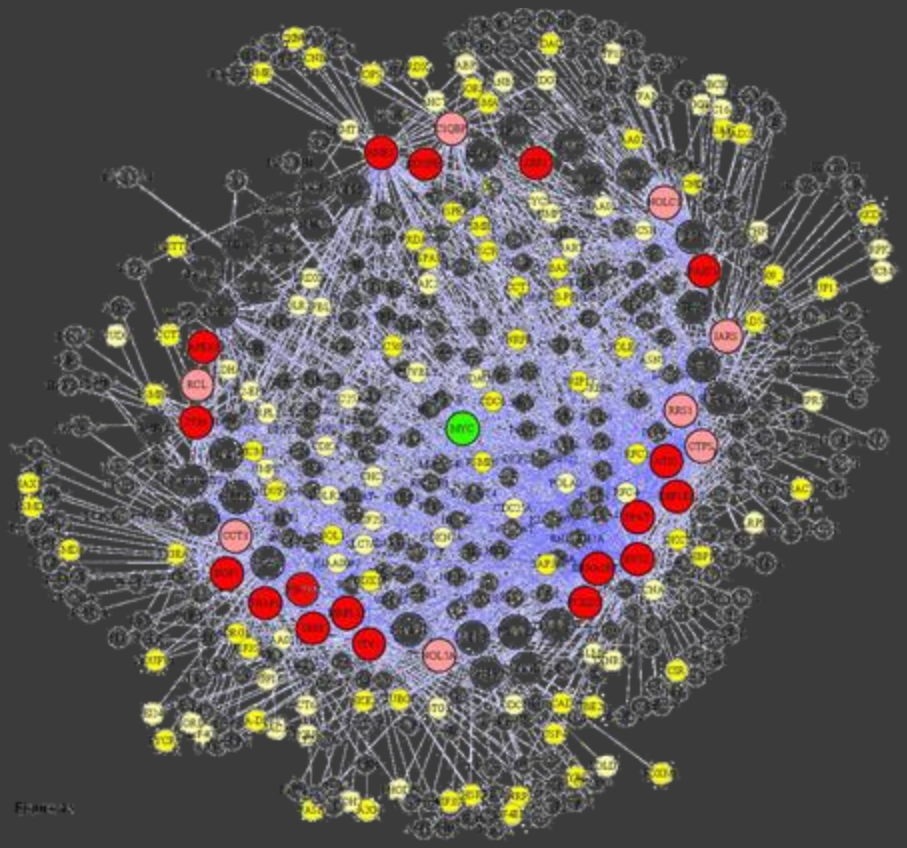


Scientific goal?

- A visualization theory that helps guide the development of automatic visualization systems: transforming data to pictures.

Explain Gene Regulatory Network

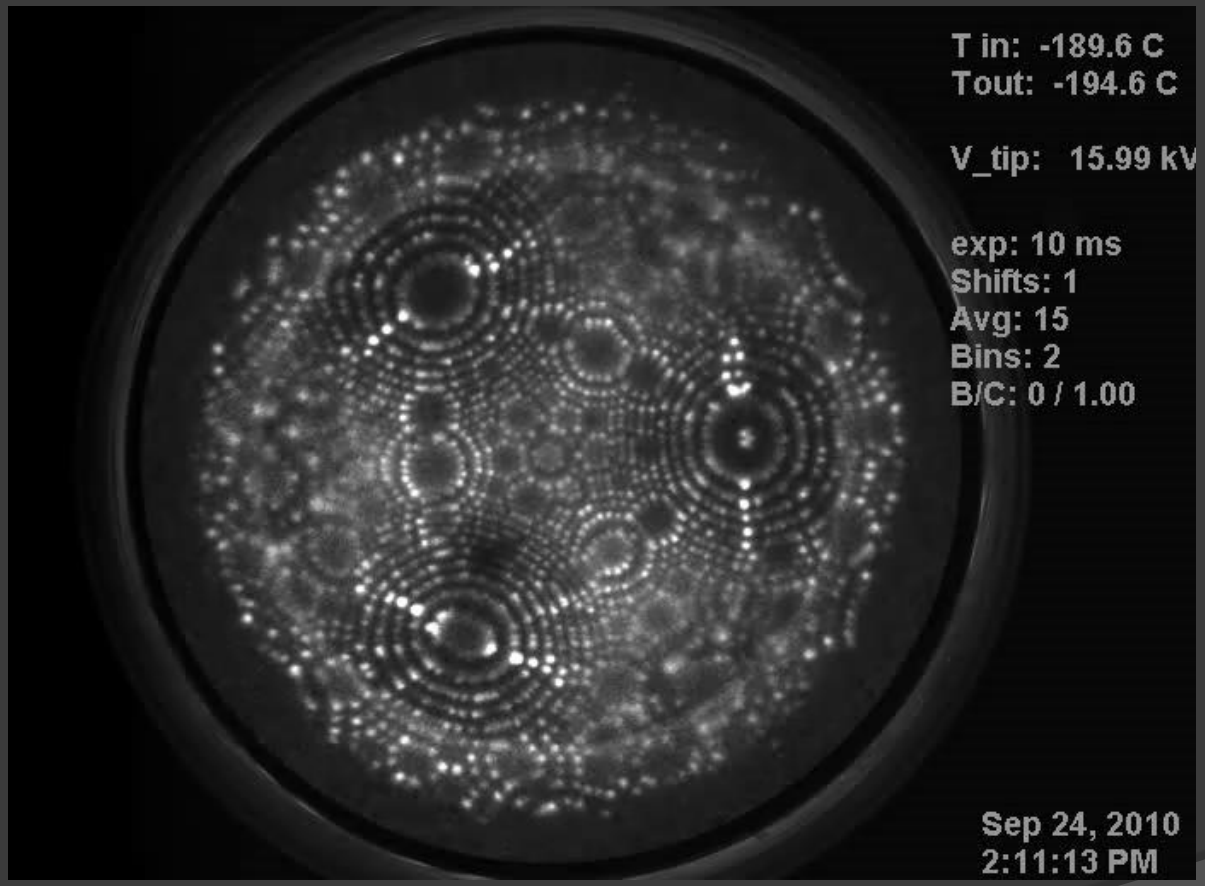


Andrea Califano et al., Reverse Engineering of Regulatory Networks in Human B Cells,
Nature Genetics ***37, 382 - 390 (2005)***

[http://www.nature.com/ng/journal/v37/n4/abs/ng1532.html]

Atom-by-atom movie of making the NINT Nano-Tip

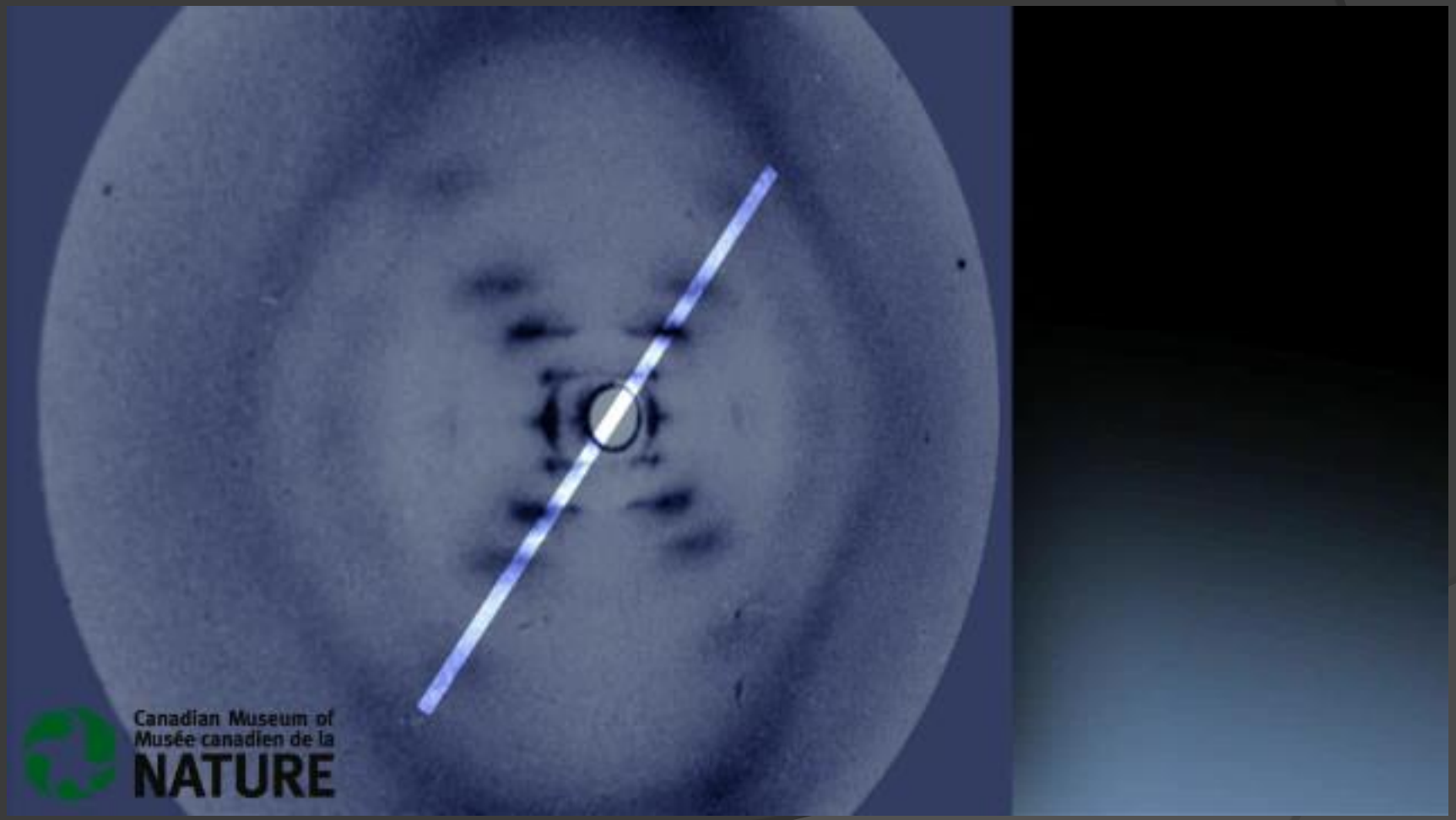
Explain World's Sharpest Object



Each white circle is a single Tungsten atom – all but the central one are controllably removed – the NINT single atom nano-tip results

Courtesy of Bob Wolkow, UofA/National Institute of Nano Technology

Explain Photo 51

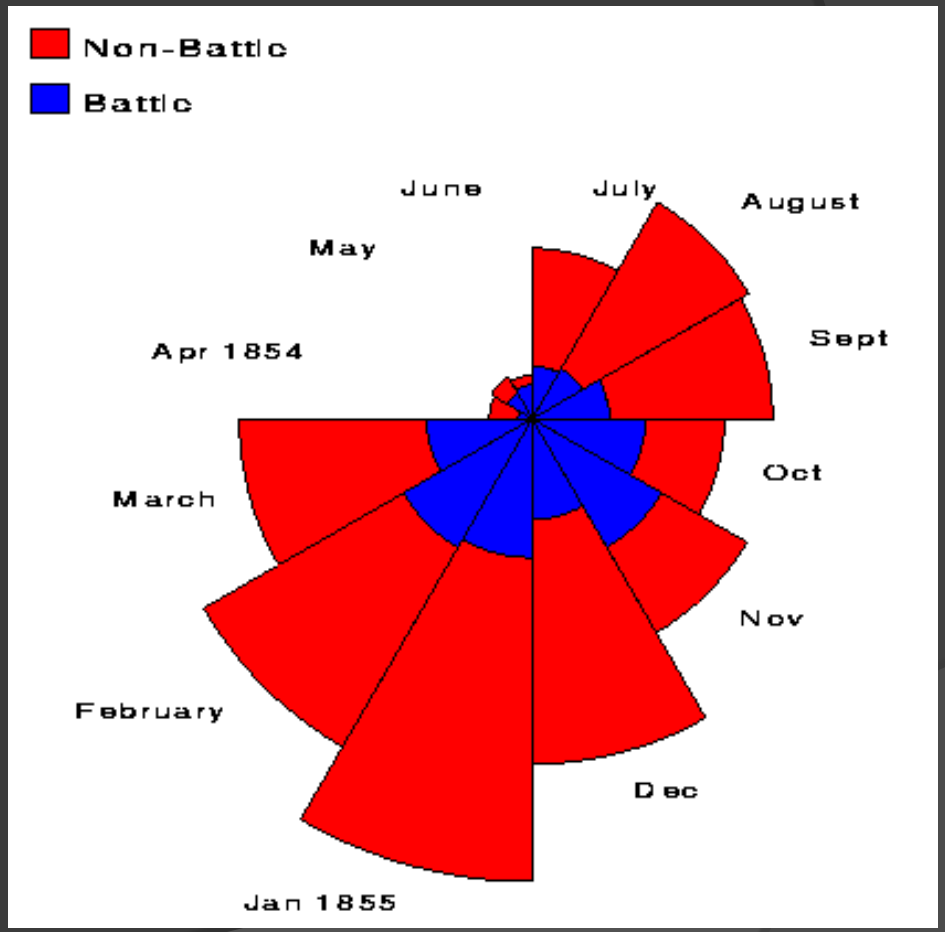


Courtesy of Jay Ingram and the Canadian Museum of Nature, see also http://en.wikipedia.org/wiki/Rosalind_Franklin

Explain Hospital vs. Battlefield Mortality

F. Nightingale (1858), "Notes on Matters Affecting the Health, Efficiency, and Hospital Administration of the British Army."

A theory is
- **Explanatory**
- **Predictive**
- **Extensible**
- **Evaluable**
- **Refutable**



Visualization Theory Components

- A theory of visualization must provide at least the following:
  - An ability to define a mapping from a non-visual to a visual domain
  - An ability to specify constraints on the intended inferences in the visual domain
  - A framework to evaluate the quality of a visualization with respect to its intended inferential goals

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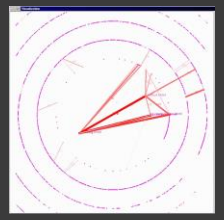
From Data to Picture

navigation visualizations (picture)

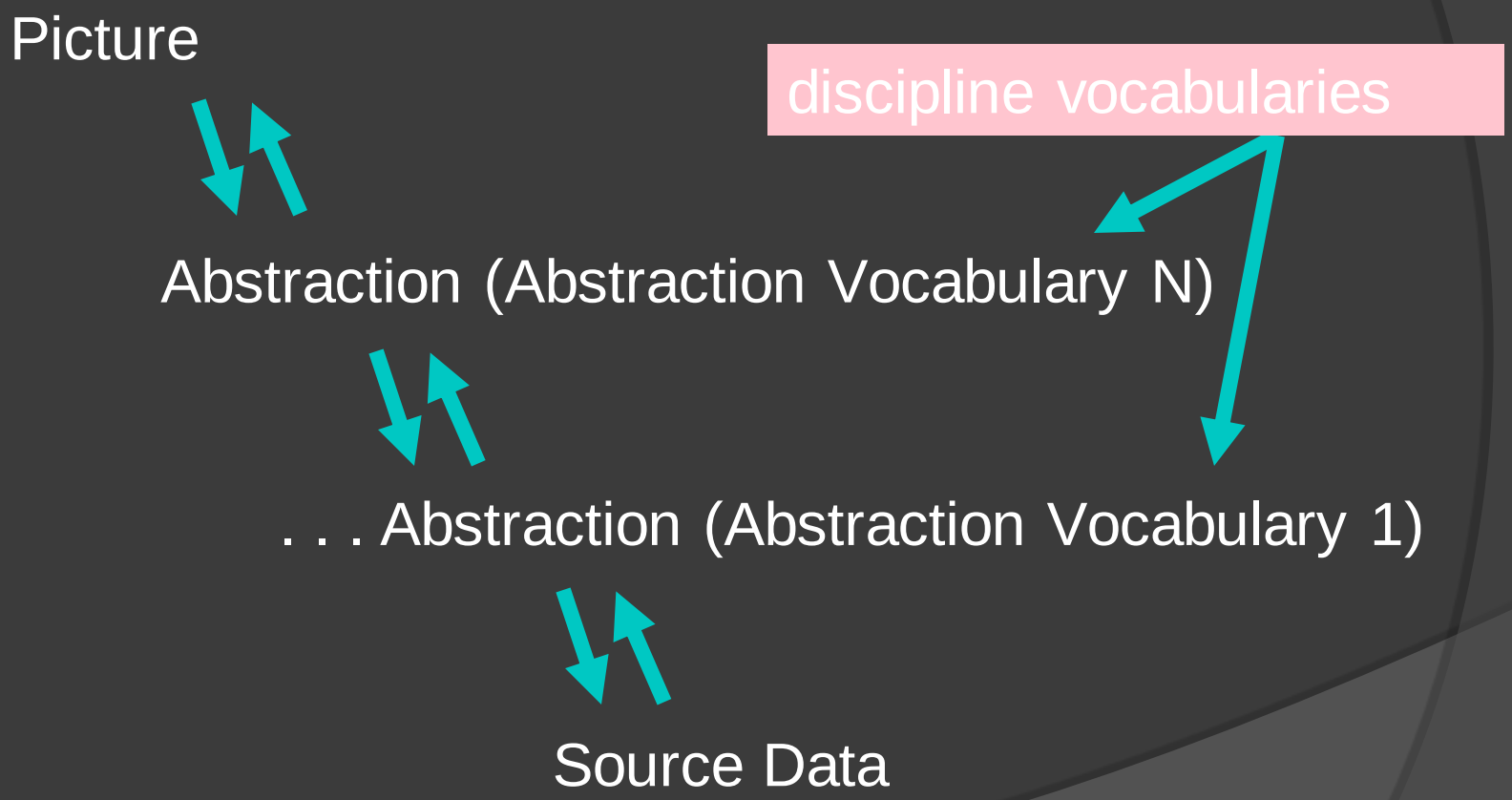


navigation compression models (abstraction vocabulary two)

session boundaries, content pages (abstraction vocabulary one)

Web logs (source data)

From Data to Picture



Humans with Machines

Humans	Machines
Adjusting models	Maintaining models
Adjusting hypotheses	Generating hypothesis
Designing Experiments	Conducting experiments

A spectrum of inference

deductive

inductive

Correct

Plausible/consistent/ambiguous

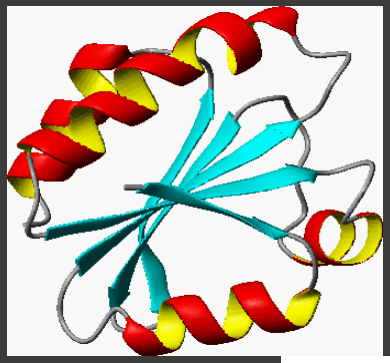
Interesting

Speculative

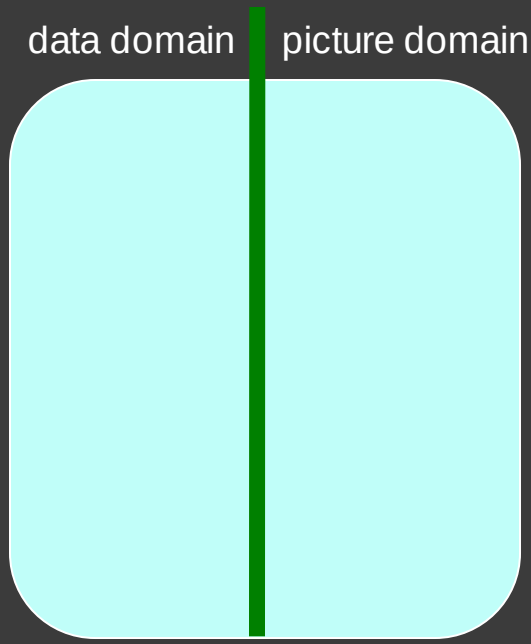
Wild-ass guess

Implausible

Wrong



Pictures, symbols, & abstraction



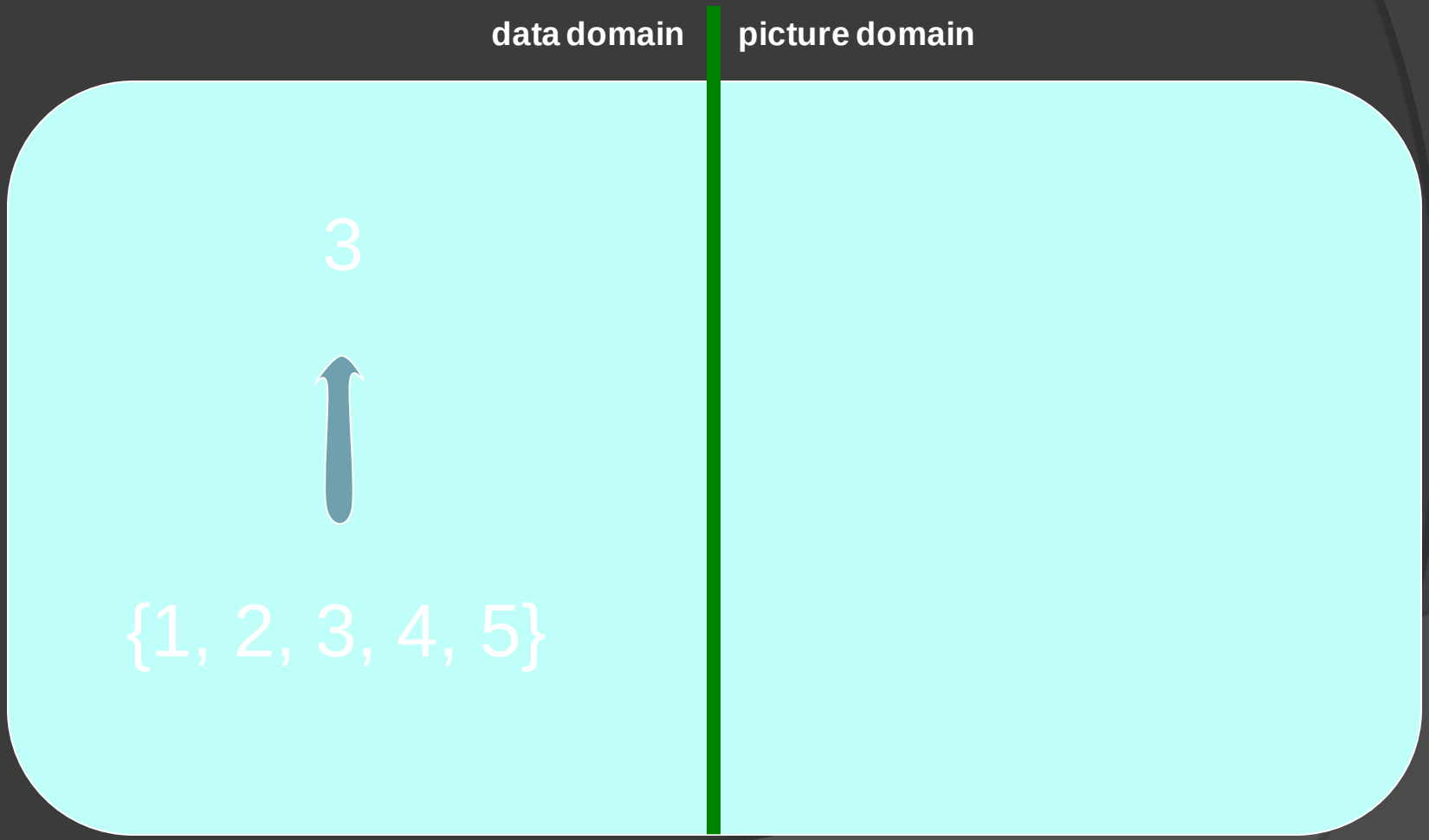
Lossy transformation

Lossless transformation

One to many transformation

Many to one transformation

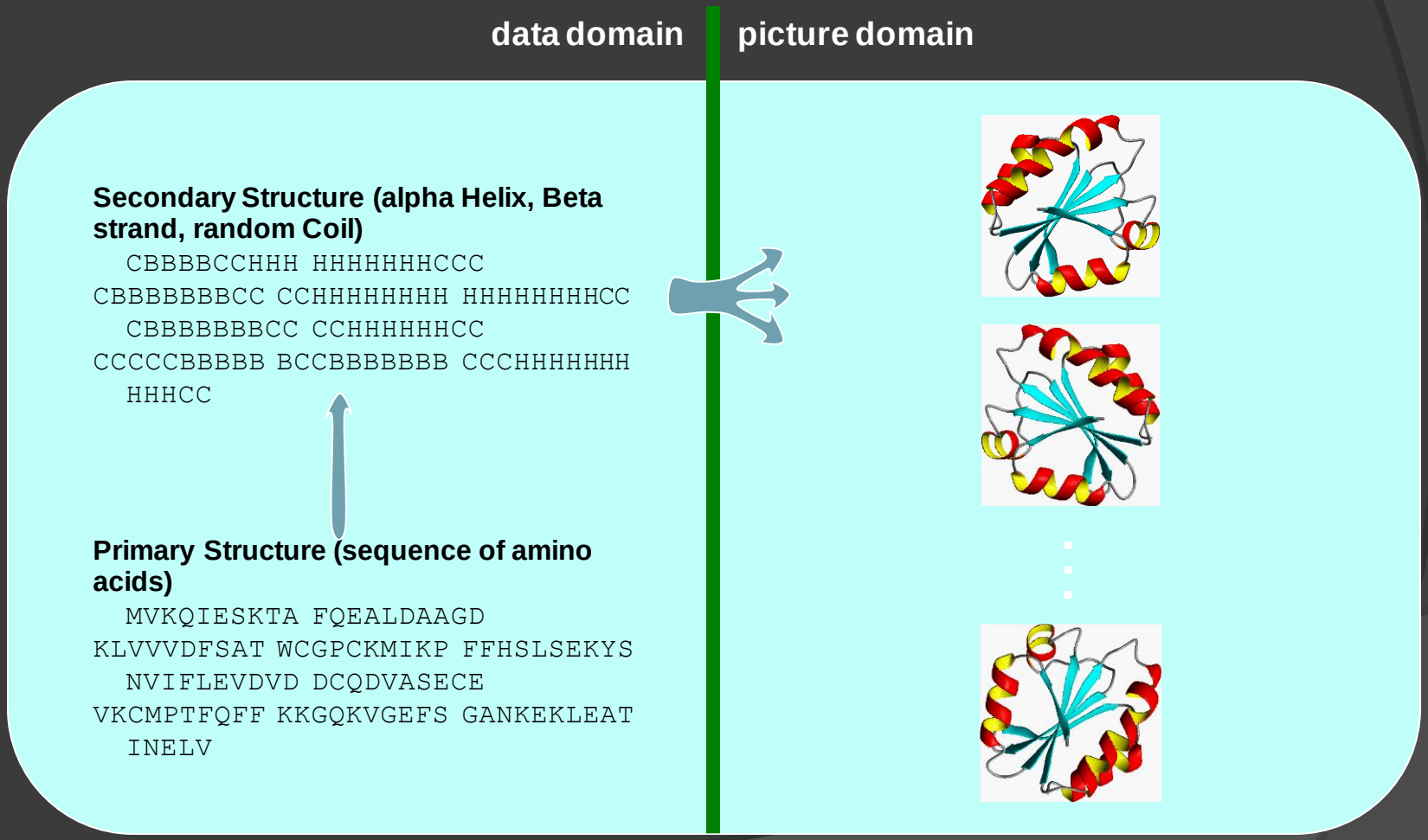
Pictures, symbols, & abstraction



Pictures, symbols, & abstraction

data domain | picture domain

Pictures, symbols, & abstraction



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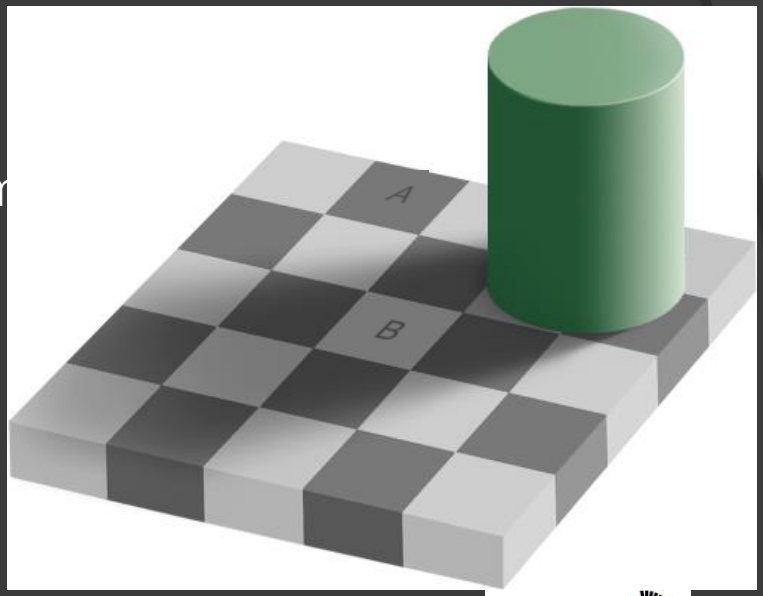
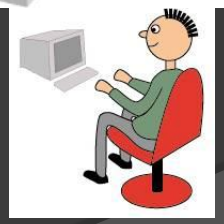
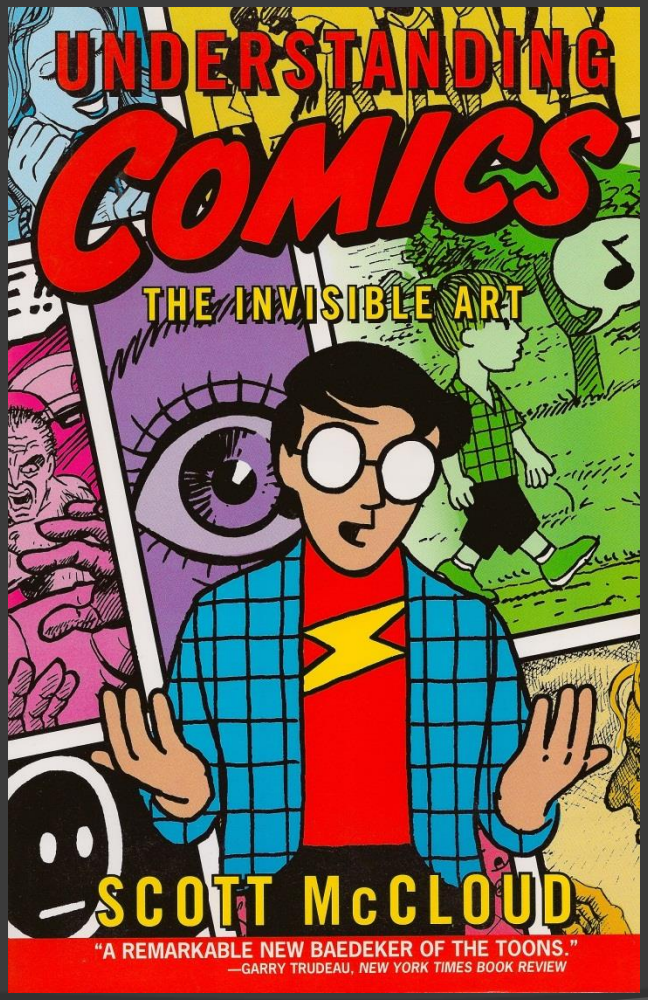




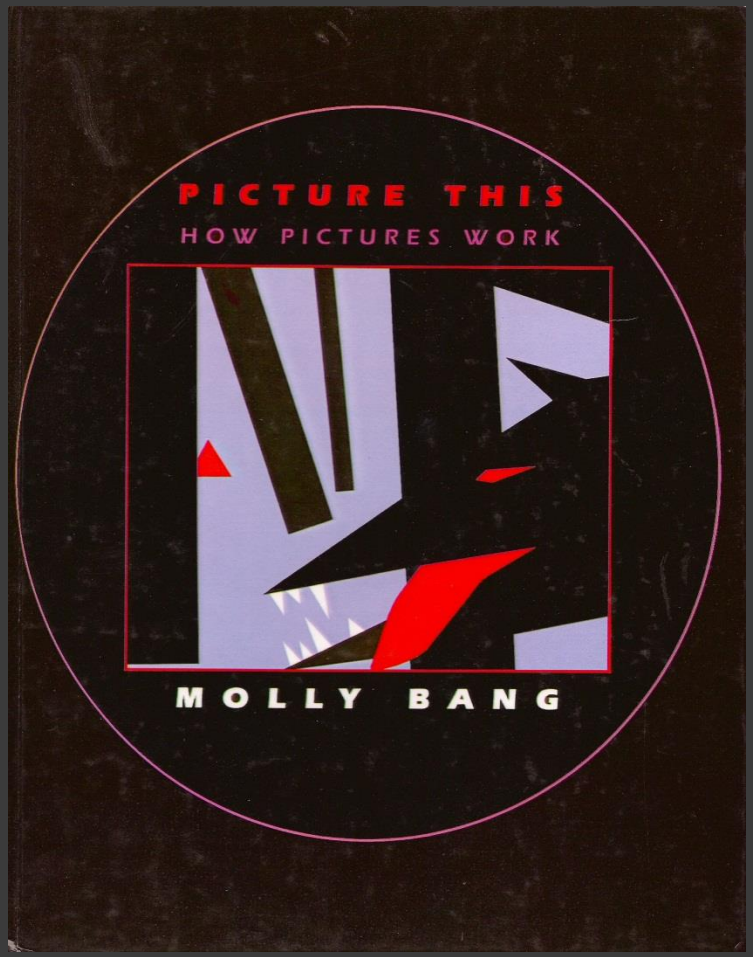
Understanding comics



- Exploiting the visual vocabulary of a graphics design/sequential art genre

http://en.wikipedia.org/wiki/Understanding_Comics

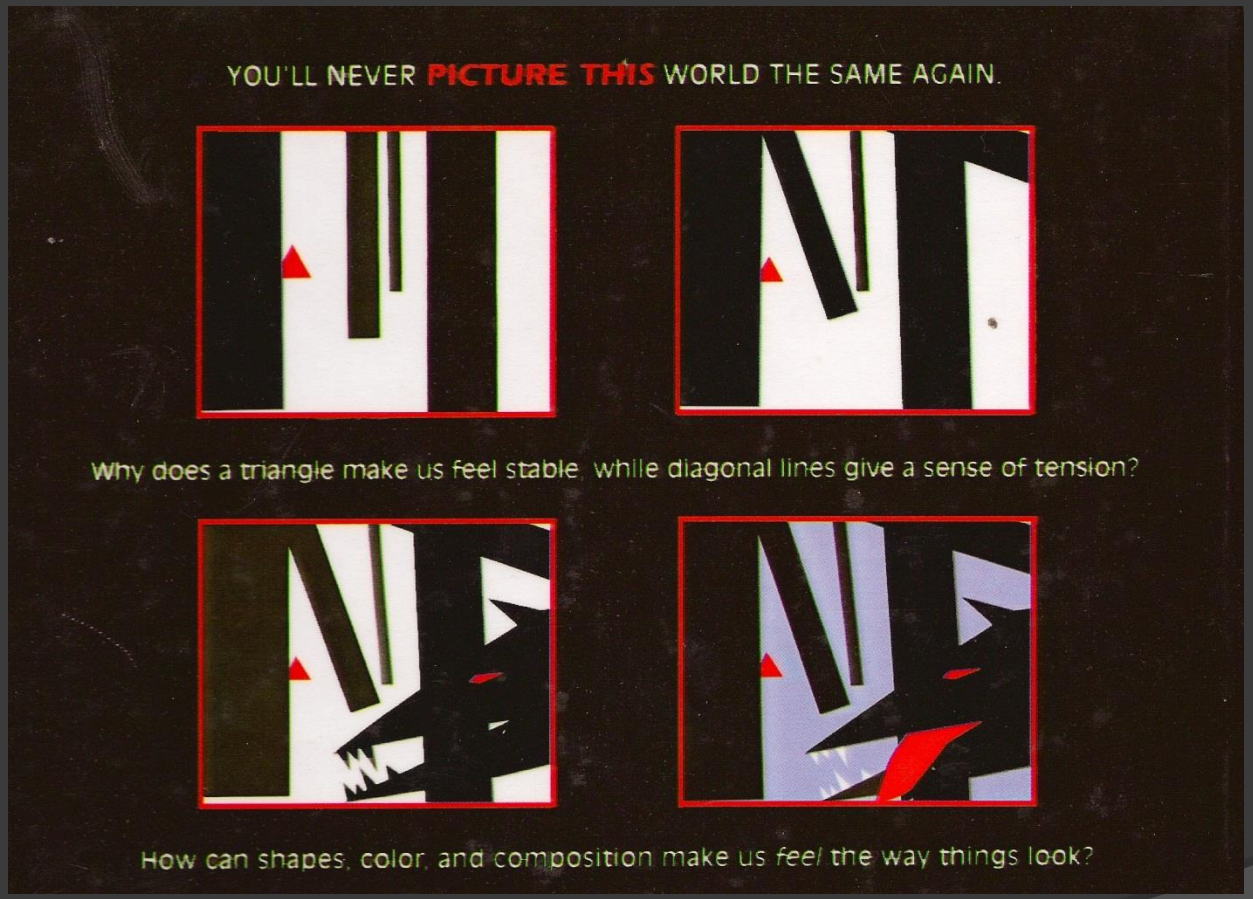
Visual Story Telling



- Refining the cognitive impact of picture-based story telling

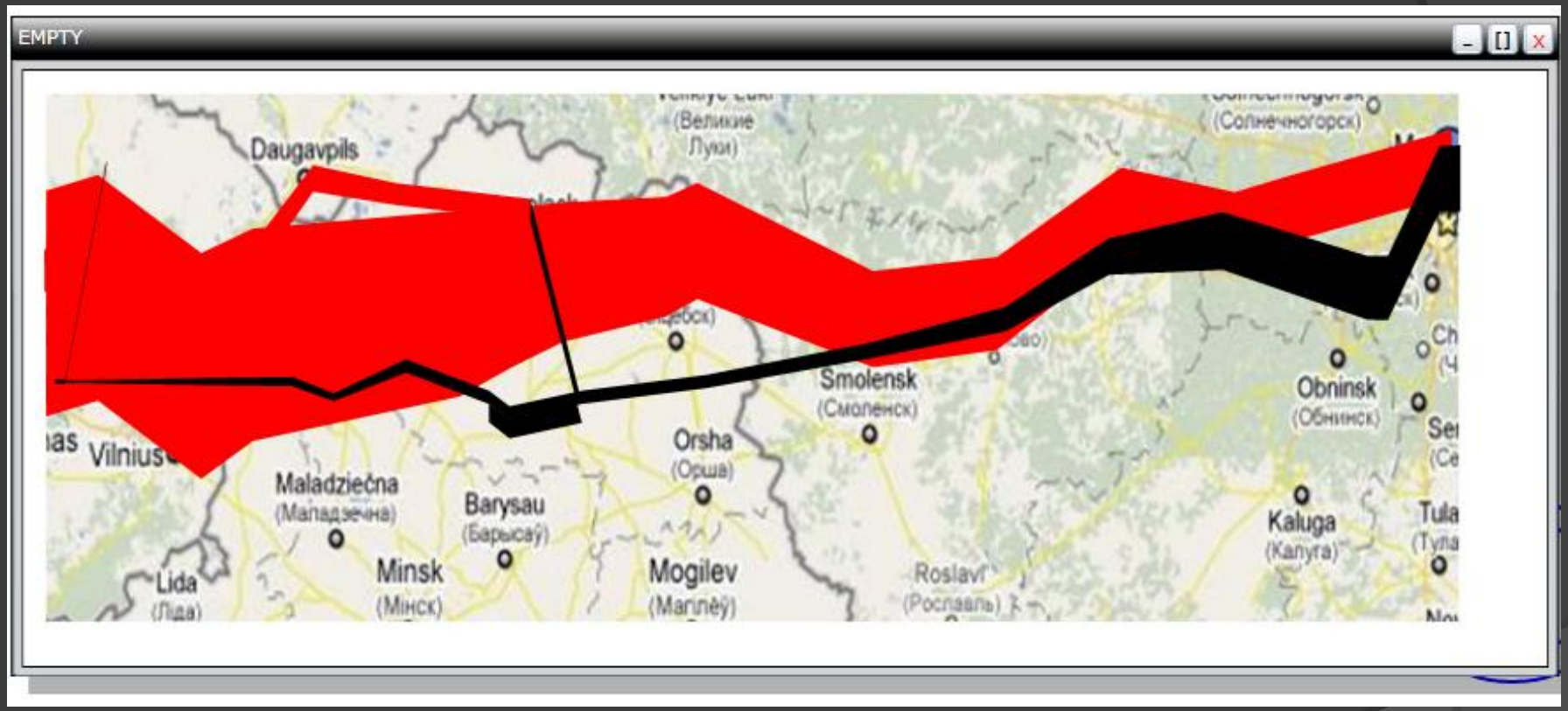
http://www.mollybang.com/Pages/picture.html

Visual Story Telling



- E.g., "Tension-inducing" graphical composition

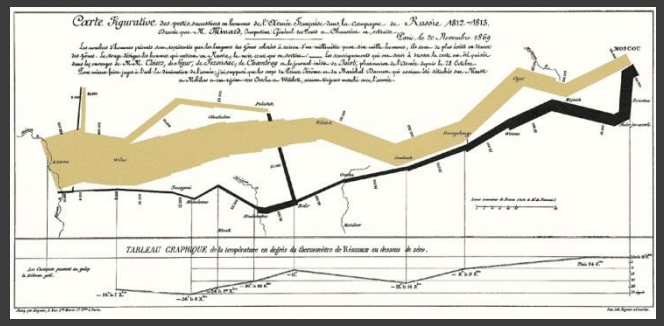
Napoleon’s chart with map



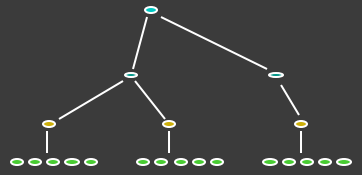
Wei Shi, Yuzuru Tanaka, Meme Laboratory, Hokkaido University, September, 2010

From Data to Picture

Minard's map



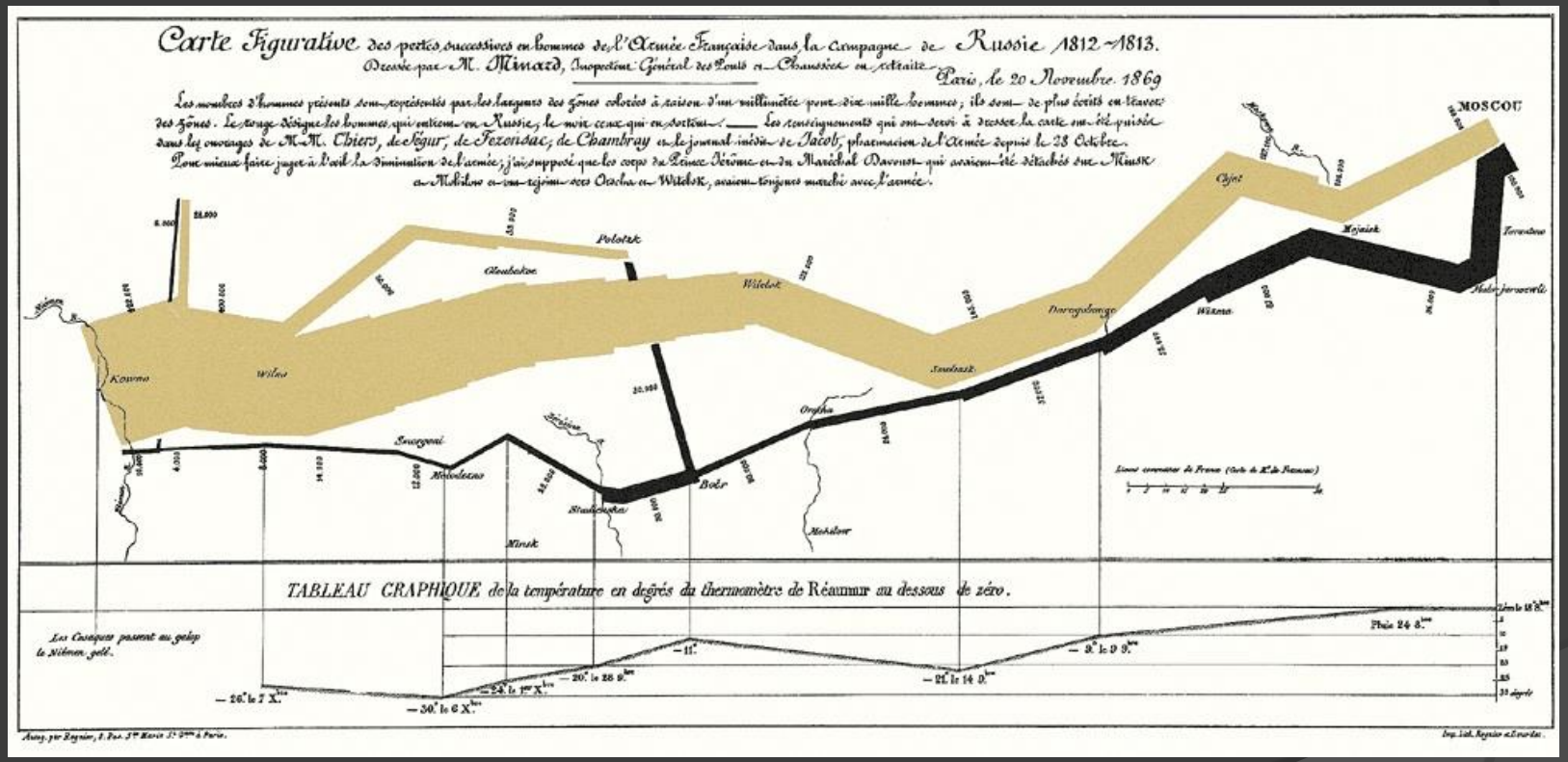
Shi's hierarchical data model



Source relational data

Date	#soldiers	Direction	Long.	Lat.	...
4/5/1812	64,464	34° NE	62.6	52.1	...
5/5/1812	63,262	30° NE	60.2	51.9	...
...	...	...	...	...	

Napolean's Moscow campaign

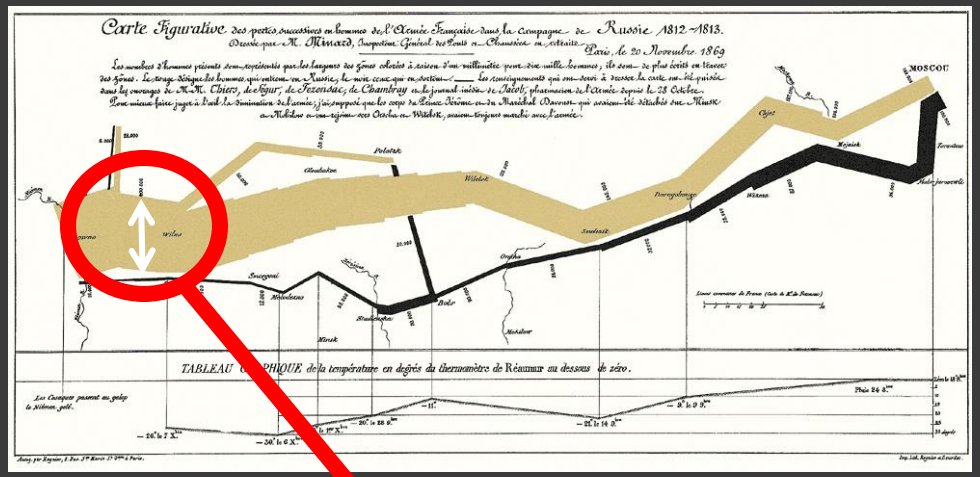


http://www.edwardtufte.com/tufte/minard/

Extracted from Edward Tufte, *The Visual Display of Quantitative Information*, 1992

Charles Joseph Minard, 1869

Semantic Symmetry by Example



Date	#soldiers	Direction		Long.	Lat.	…
4/5/1812	64,464	34°	NE	62.6	52.1	…
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…	…	…		…	…	

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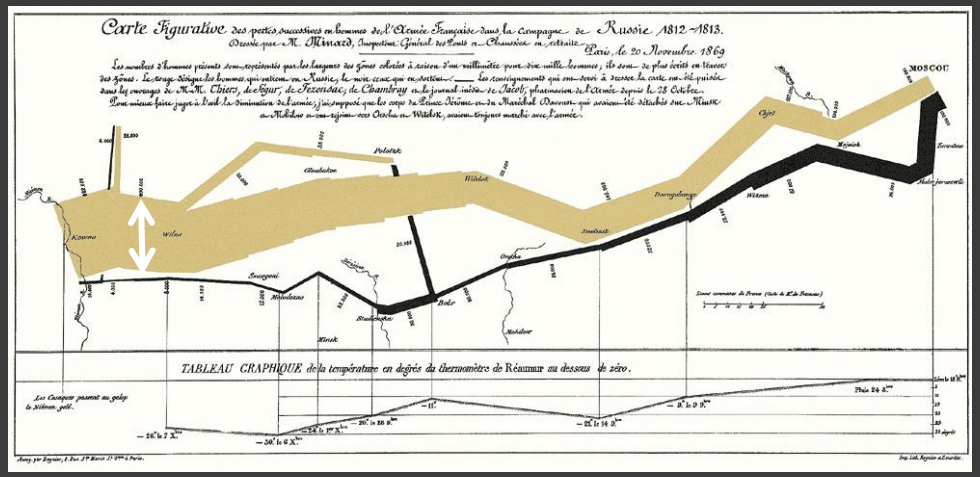

Date	#soldiers	Direction	Long.	Lat.	…
4/5/1812	64,464	34° NE	62.6	52.1	…
5/5/1812	63,262	30° NE	60.2	51.9	…
…	…	…	…	…	

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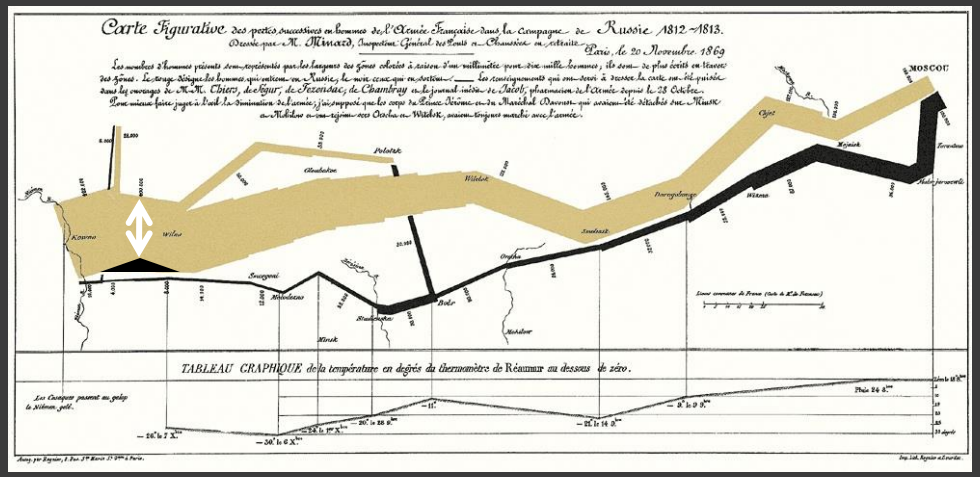
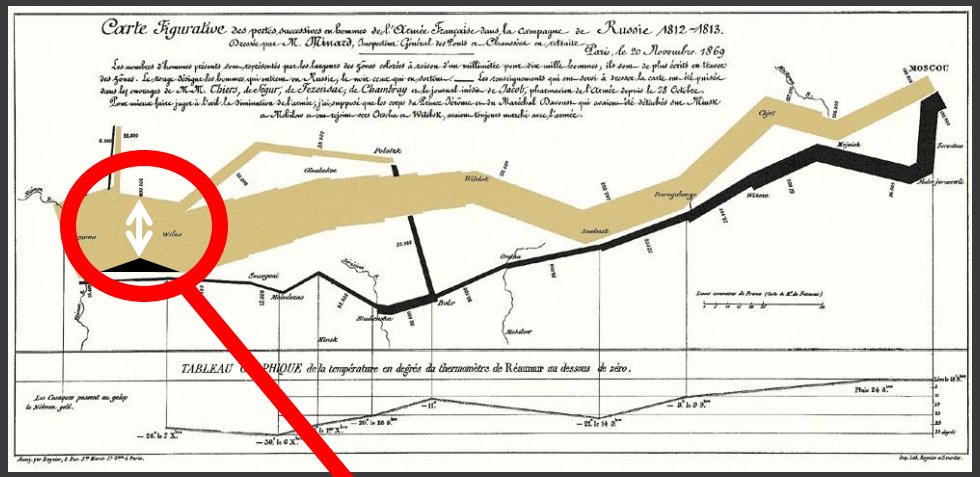


Date	#soldiers	Direction	Long.	Lat.	…
4/5/1812	64,464	34° NE	62.6	52.1	…
5/5/1812	47,444	30° NE	60.2	51.9	…
…	…	…	…	…	

Semantic Symmetry by Example



Date	#soldiers	Direction	Long.	Lat.	…
4/5/1812	64,464	34° NE	62.6	52.1	…
5/5/1812	47,444	30° NE	60.2	51.9	…
…	…	…	…	…	

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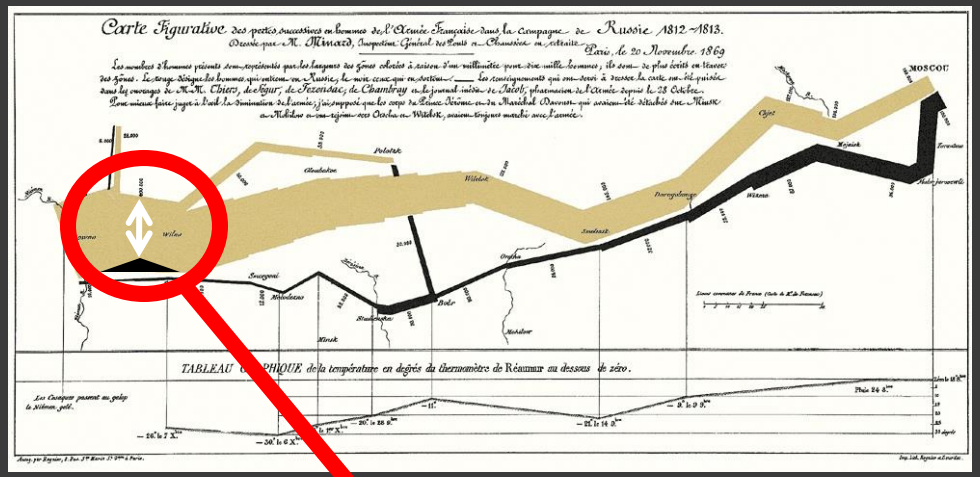

Date	#soldiers	Direction	Long.	Lat.	…
4/5/1812	64,464	34° NE	62.6	52.1	…
5/5/1812	?	30° NE	60.2	51.9	…
…	…	…	…	…	

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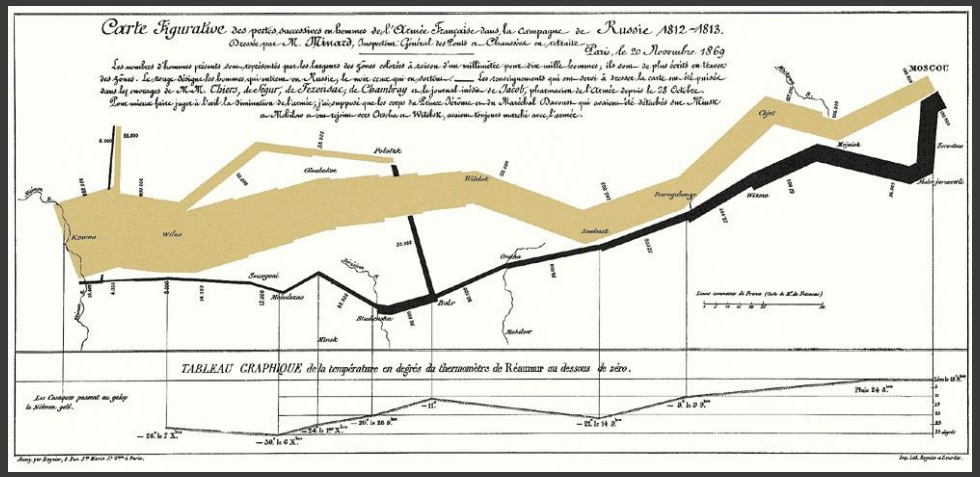
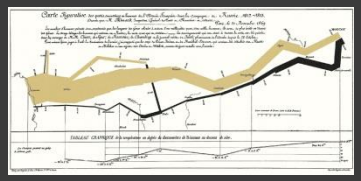
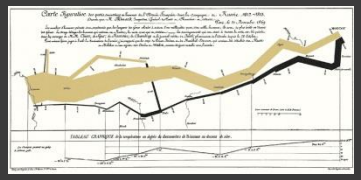


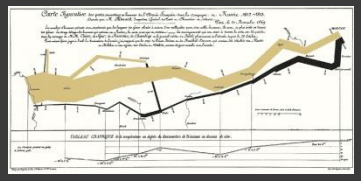
- How does change propagate?
- Are changes monotonic or non-monotonic?
- Can change be used to both validate a model, and to suggest experiments?

Date	#soldiers	Direction	Long.	Lat.	…
4/5/1812	64,464	34° NE	62.6	52.1	…
5/5/1812	63,262	30° NE	60.2	51.9	…
…	…	…	…	…	

Bilateral propagation structure







Date	#soldiers	Direction	Long.	Lat.	...
4/5/1812	64,464	34° NE	62.6	52.1	...
5/5/1812	63,262	30° NE	60.2	51.9	...
...	...	...	...	...	

Date	#soldiers	Direction	Long.	Lat.	...
4/5/1812	64,464	34° NE	62.6	52.1	...
5/5/1812	63,262	30° NE	60.2	51.9	...
...	...	...	...	...	

. . .

Veracity of visual inferences

Truth preserving	Consistent hypothesis	Unverified guess	Avoidable artifact	Artistic expression
Deduction	Induction		Careless design of visual vocabulary, or of rendering, or both	Aesthetic license with no explicit intention of veracity
Confirmable semantic symmetry	Abduction, belief revision	Syntactically driven induction	Disconnect between syntax and semantics	Individual creativity in connection between syntax and semantics

Escher's Waterfall

Maurits Cornelis Escher

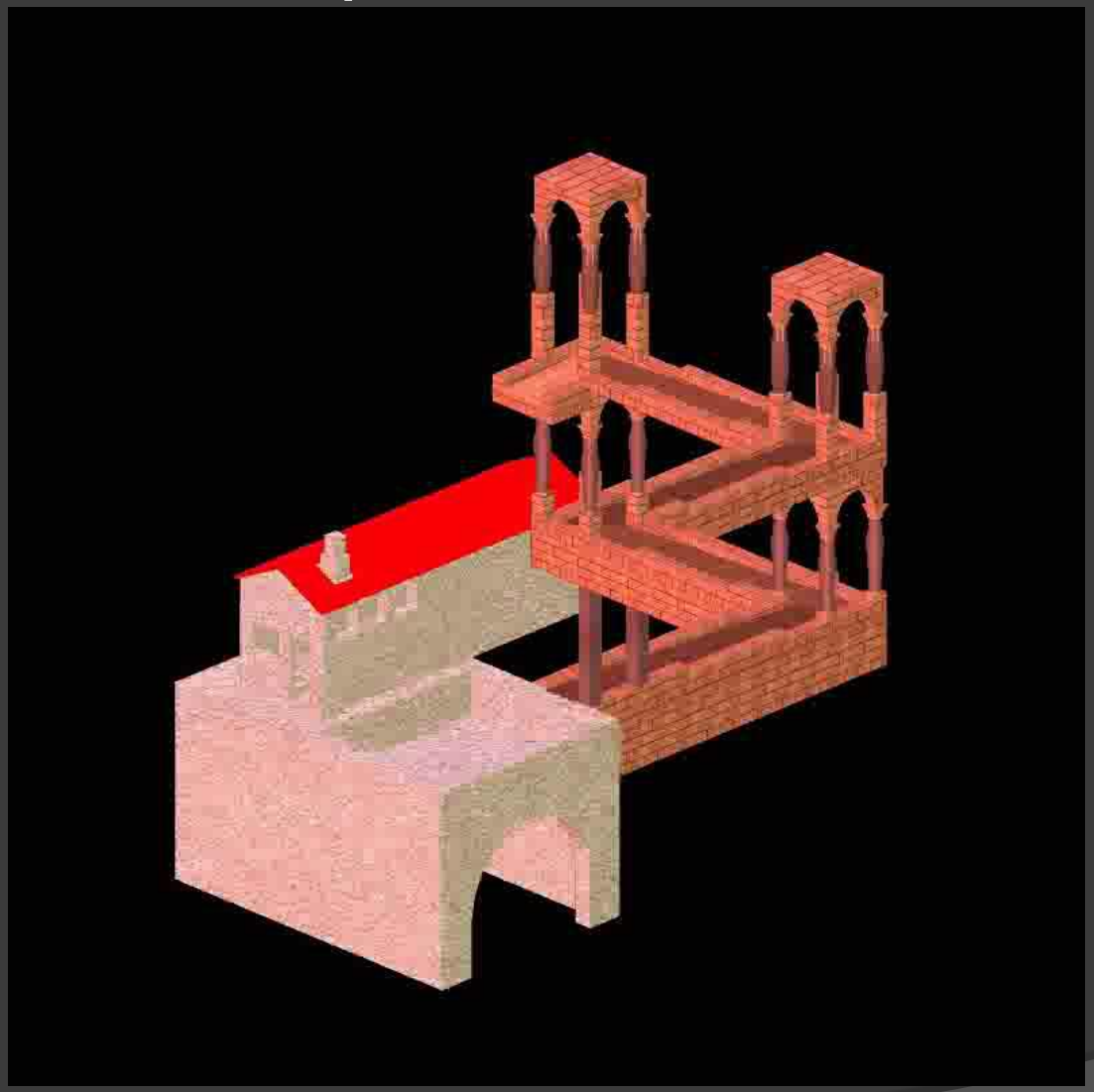
A 1929 self-portrait

Born	17 June 1898 Leeuwarden, The Netherlands
Died	27 March 1972 (aged 73) Laren, The Netherlands
Nationality	Dutch
Field	Drawing, Printmaking
Works	Relativity, Waterfall, Hand with Reflecting Sphere
Influenced by	Giovanni Battista Piranesi
Awards	Knighthood of the Order of Orange-Nassau

A theory is

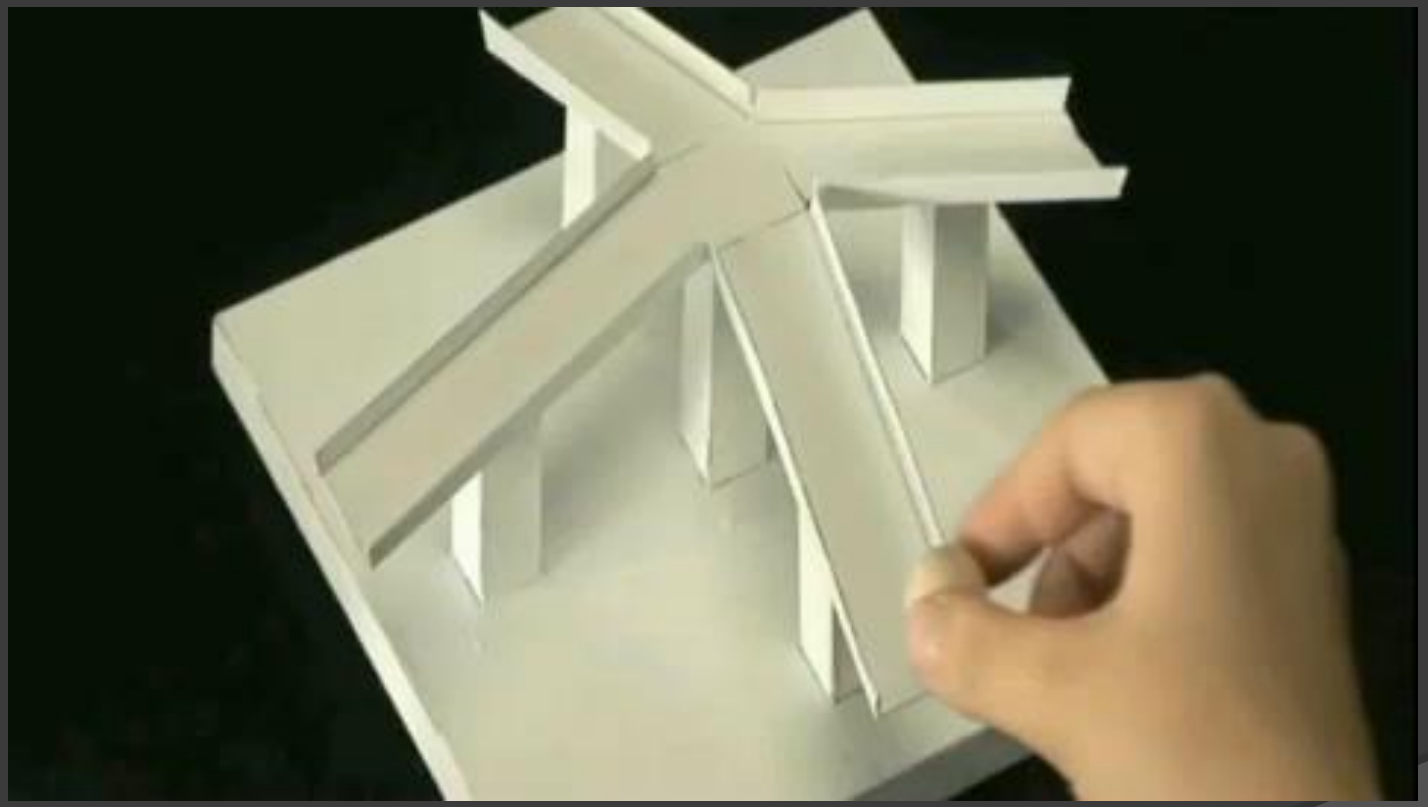
- **Explanatory**
- **Predictive**
- **Extensible**
- **Evaluable**
- **Refutable**

One explanation of Escher's Waterfall



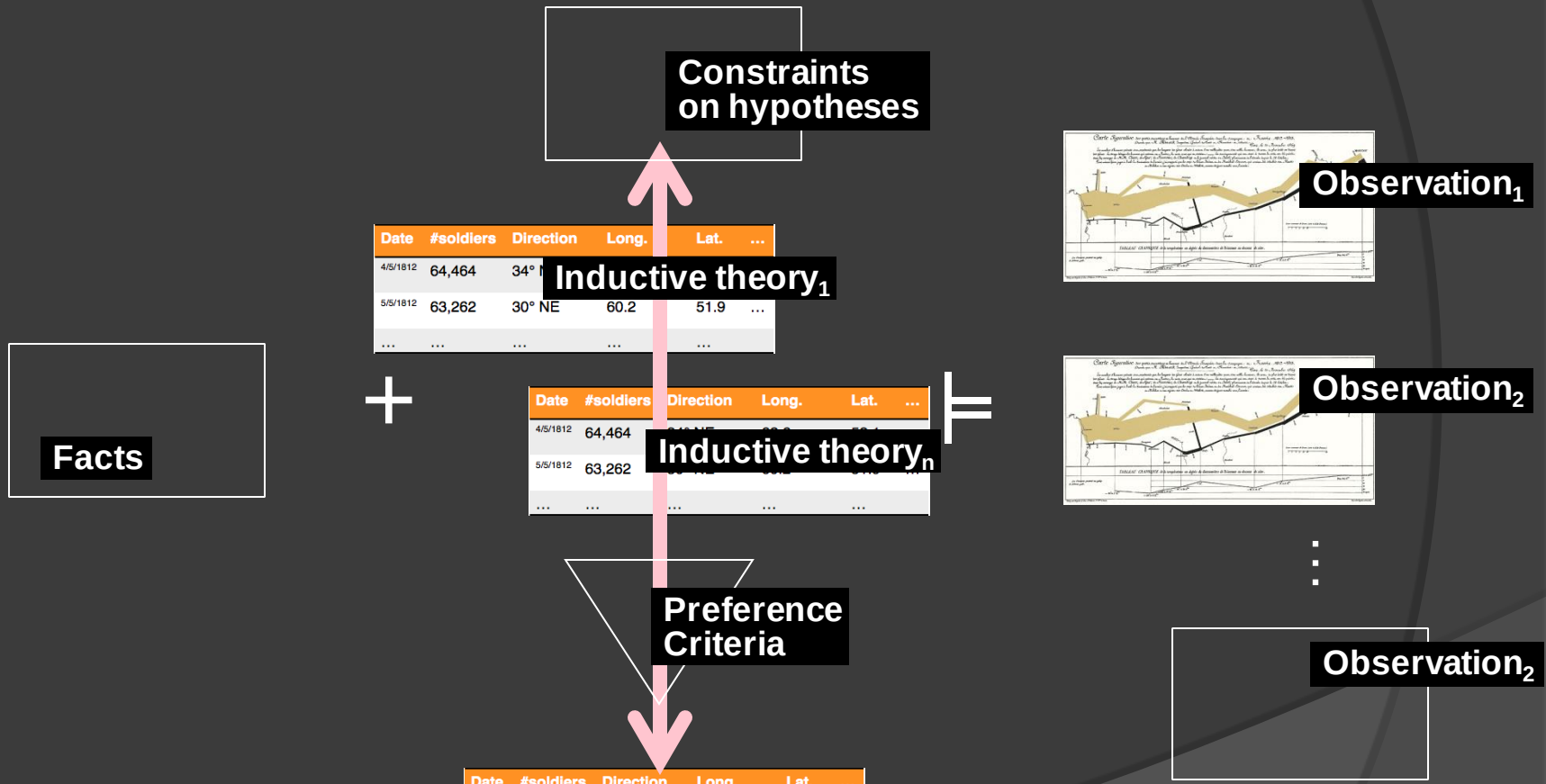
http://www.cs.technion.ac.il/~gershon/EscherForReal/

Sugihara's "impossible" objects

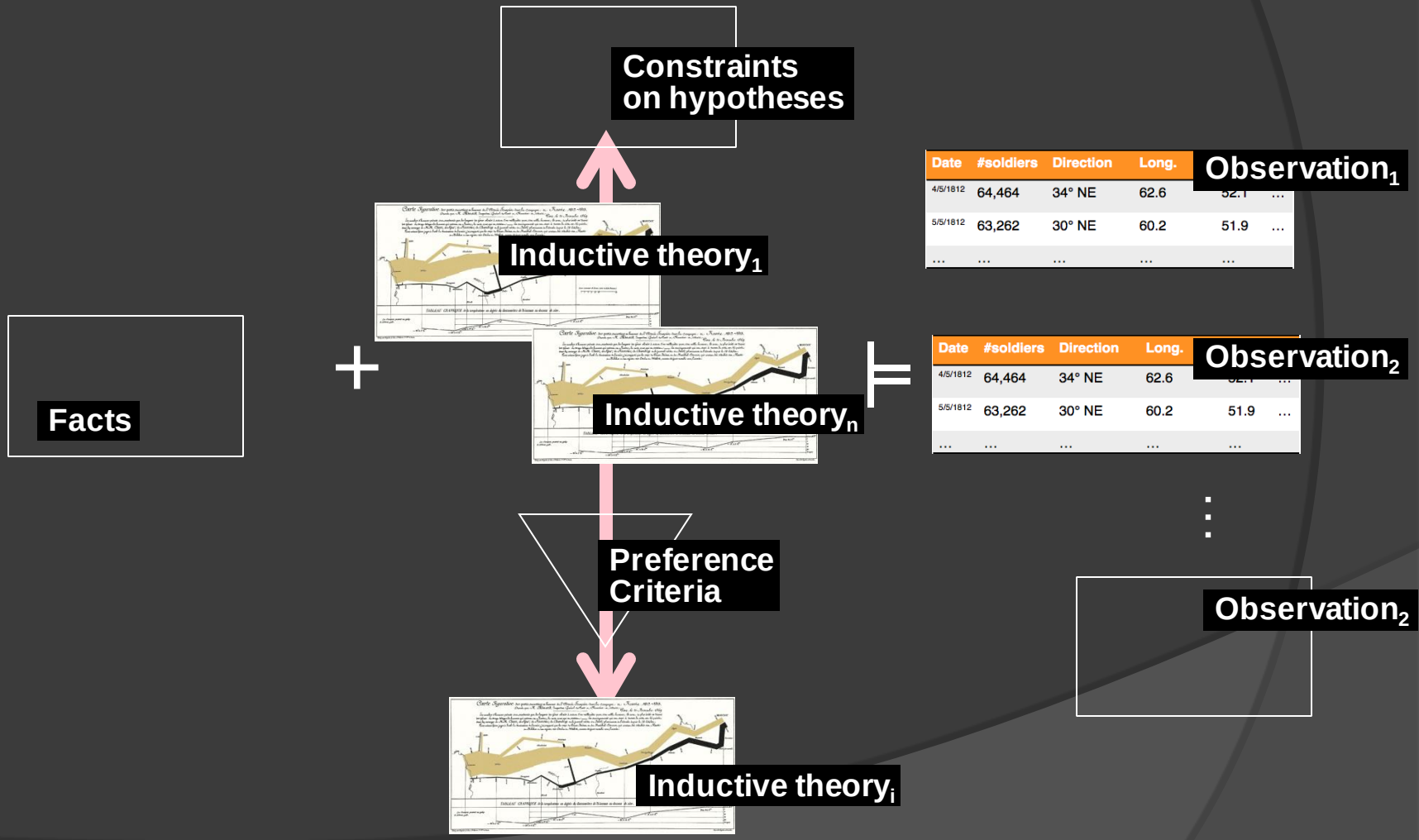


http://home.mims.meiji.ac.jp/~sugihara/hobby/MagnetLikeSlopes.wmv

Abductive Reasoning



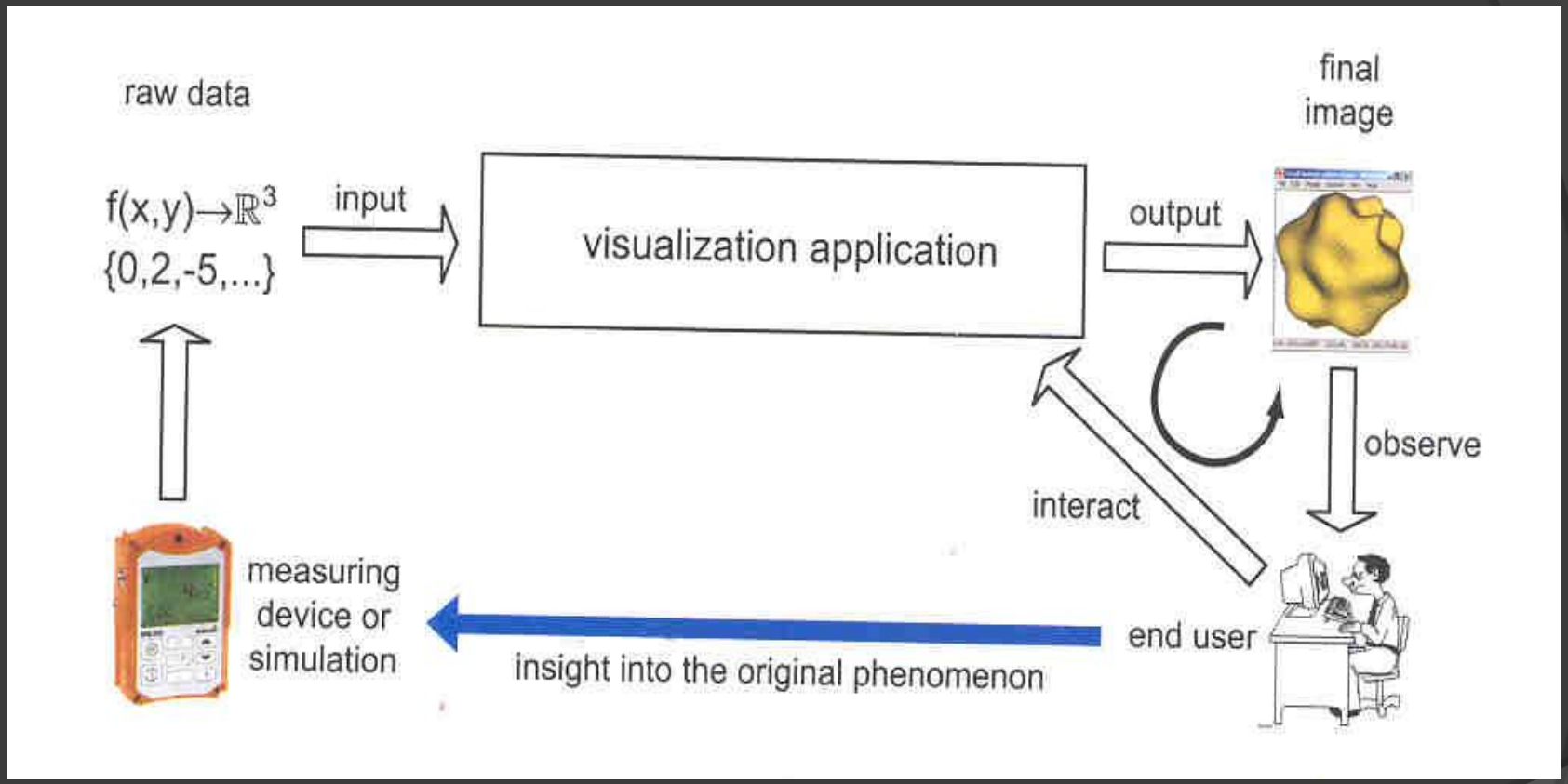
Abductive Reasoning



Summary & Conclusions

- **Components of a visualization theory exist, but are not yet connected:**
  - Mappings from sub-visual to visual, but not much the other way around
  - Typically only implicit constraints on semantics inferential intent
  - Only recently increasing emphasis on evaluation of alternative visualization methods with same inferential intent
- **Semantic symmetry: one possible framework for both *use* and *evaluation* of visualization constraint manipulation.**
  - Semantic symmetry operations require semantic conceptions of components of visualization data chain..
  - Formalizations of visual operations are required, to define propagation of changes through the visualization data lattice

Visualization Pipeline

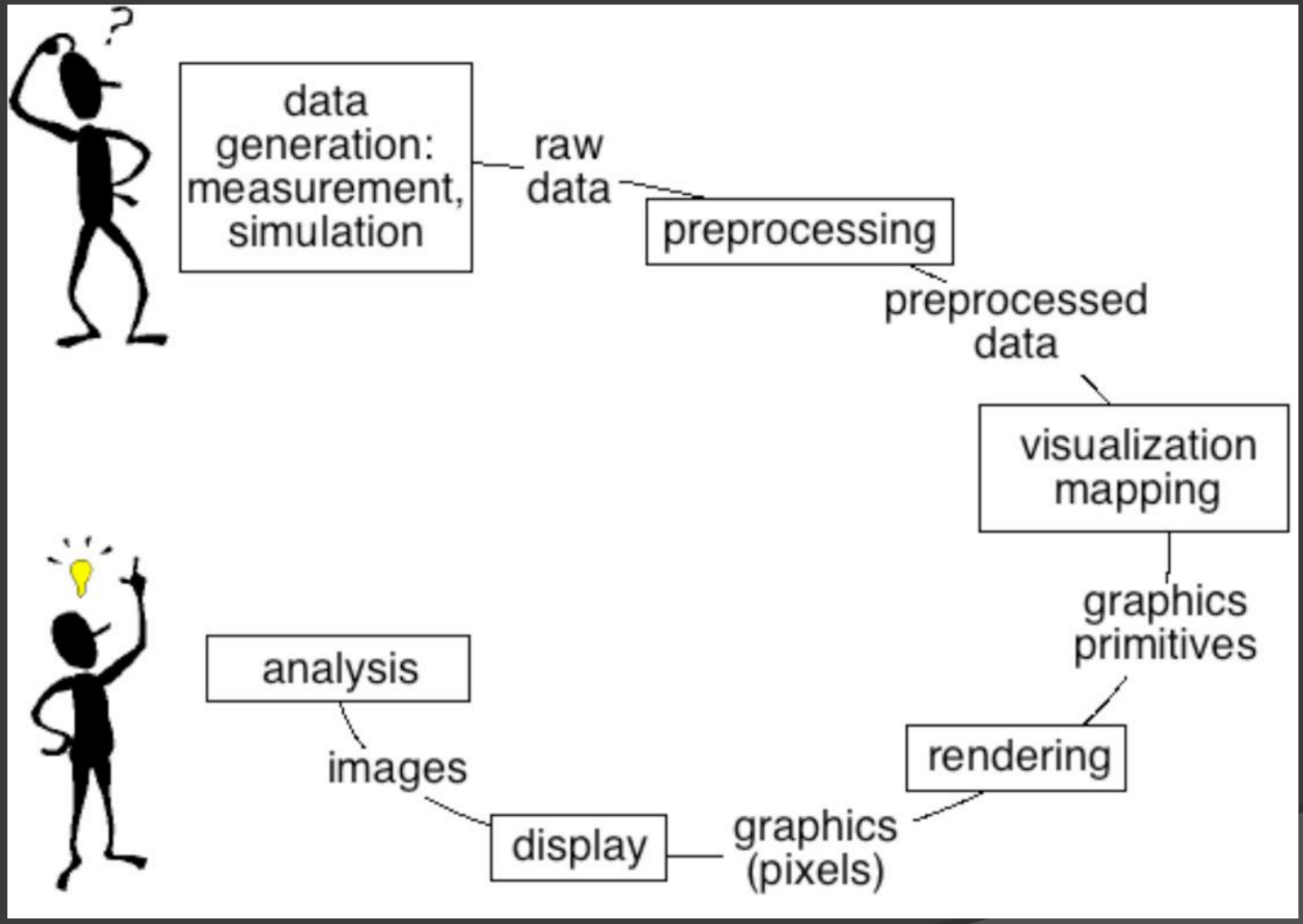


Conceptual View of Visualization Process

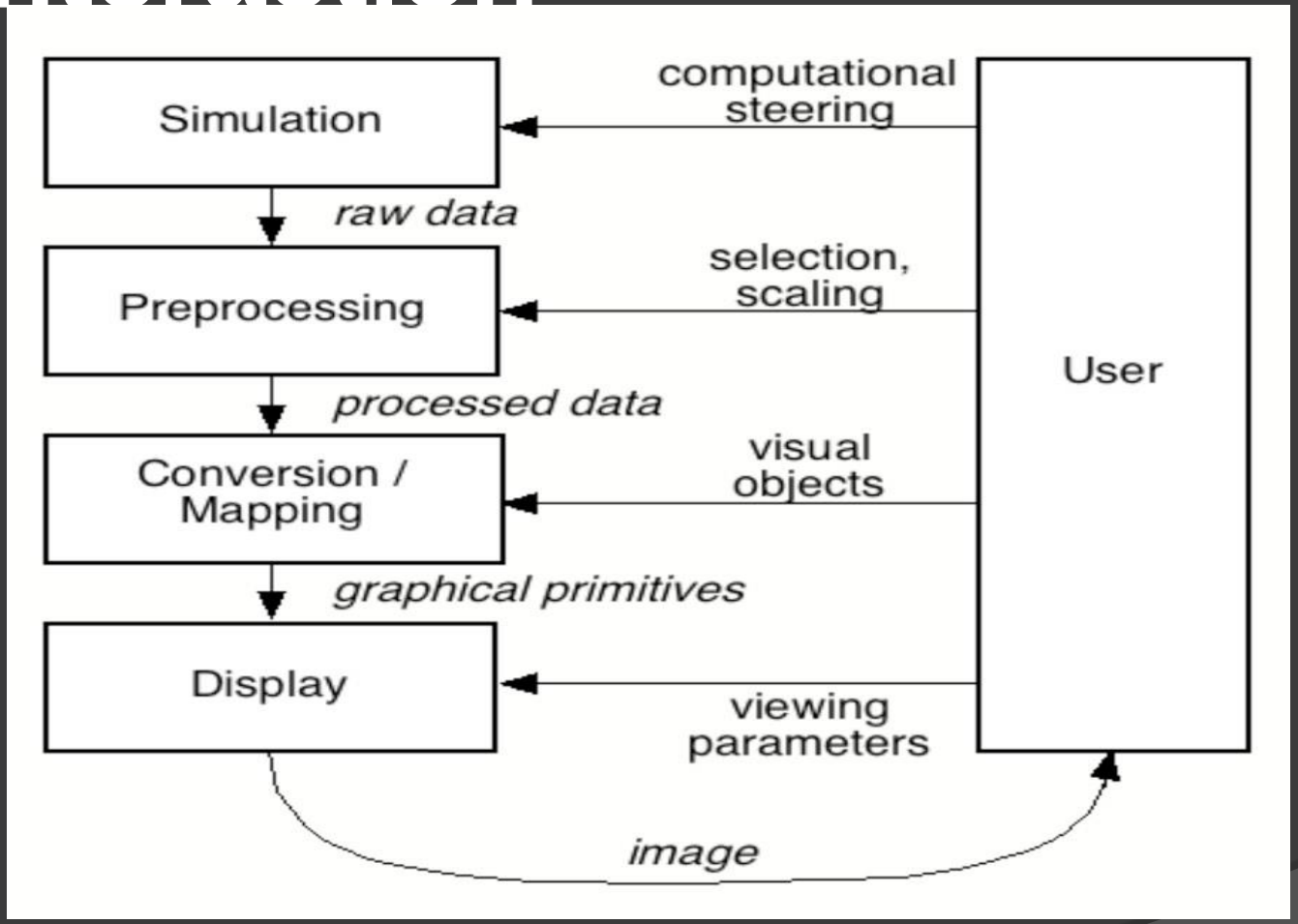
Visualization Process

- Acquisition: data of interest into a discrete dataset;
- Mapping: dataset into graphics primitives;
- Rendering: generation of requested images.

Visualization Process



Visualization process: interaction



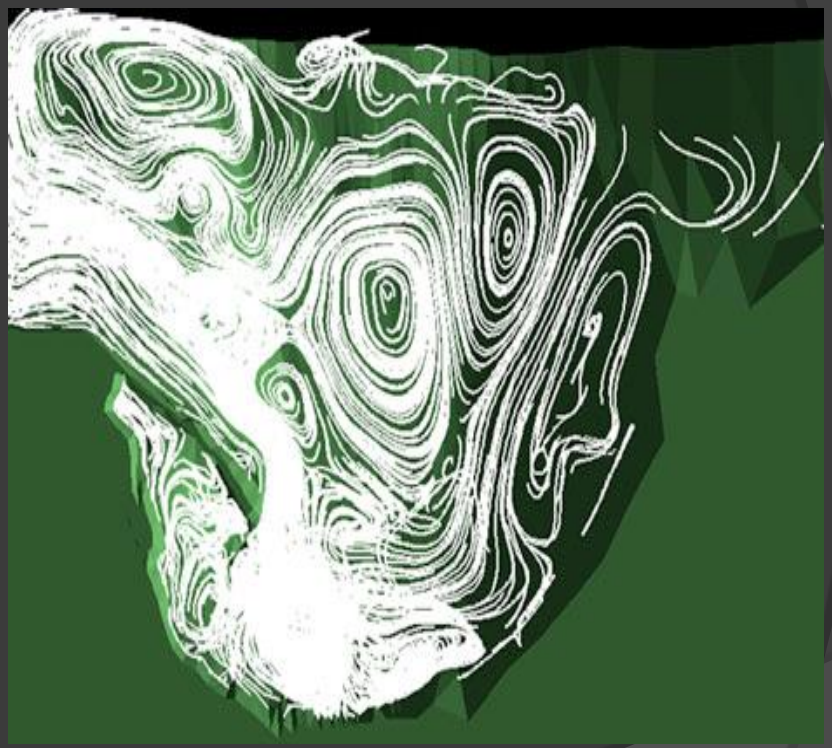
Classification

- Scientific visualization (scivis)
- Information visualization (infovis)
- Visual Analytics: a new subject

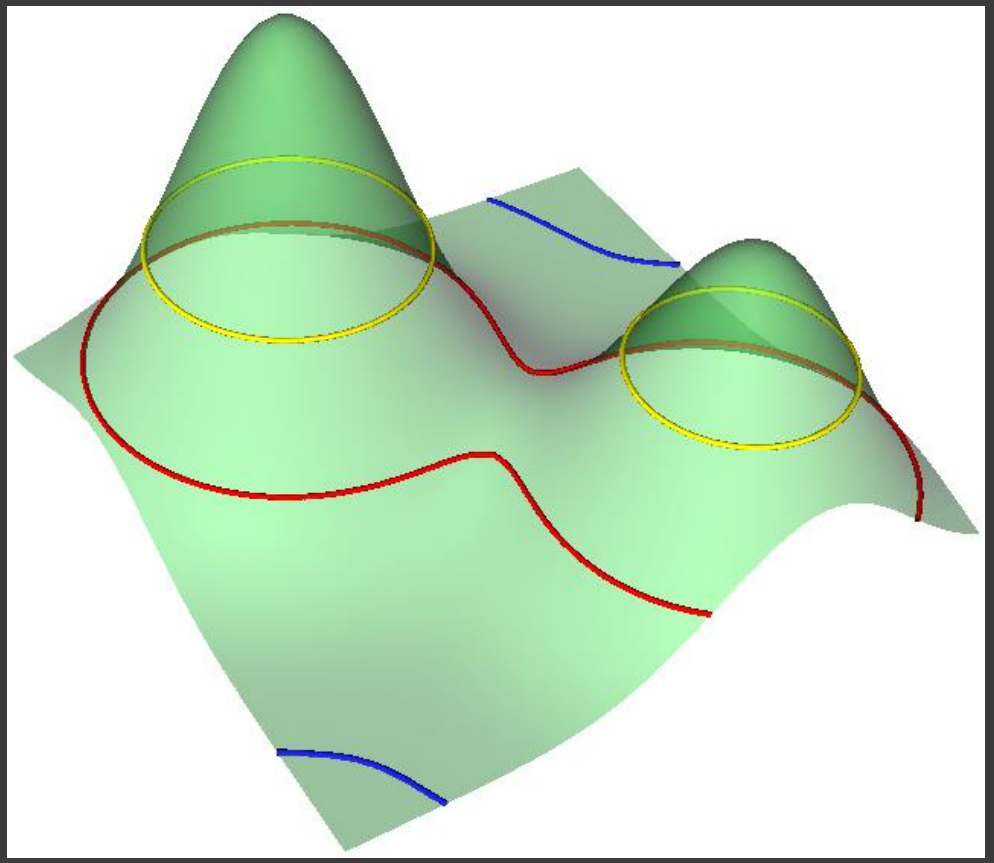
Scientific Visualization (ViSC: Visualization in Scientific Computing)

Numerical data from measurements (data acquisition devices), or from computer simulations

- scientific / engineering / biomedical
- numerical, physical
- clear reference frame
- goal: insight!

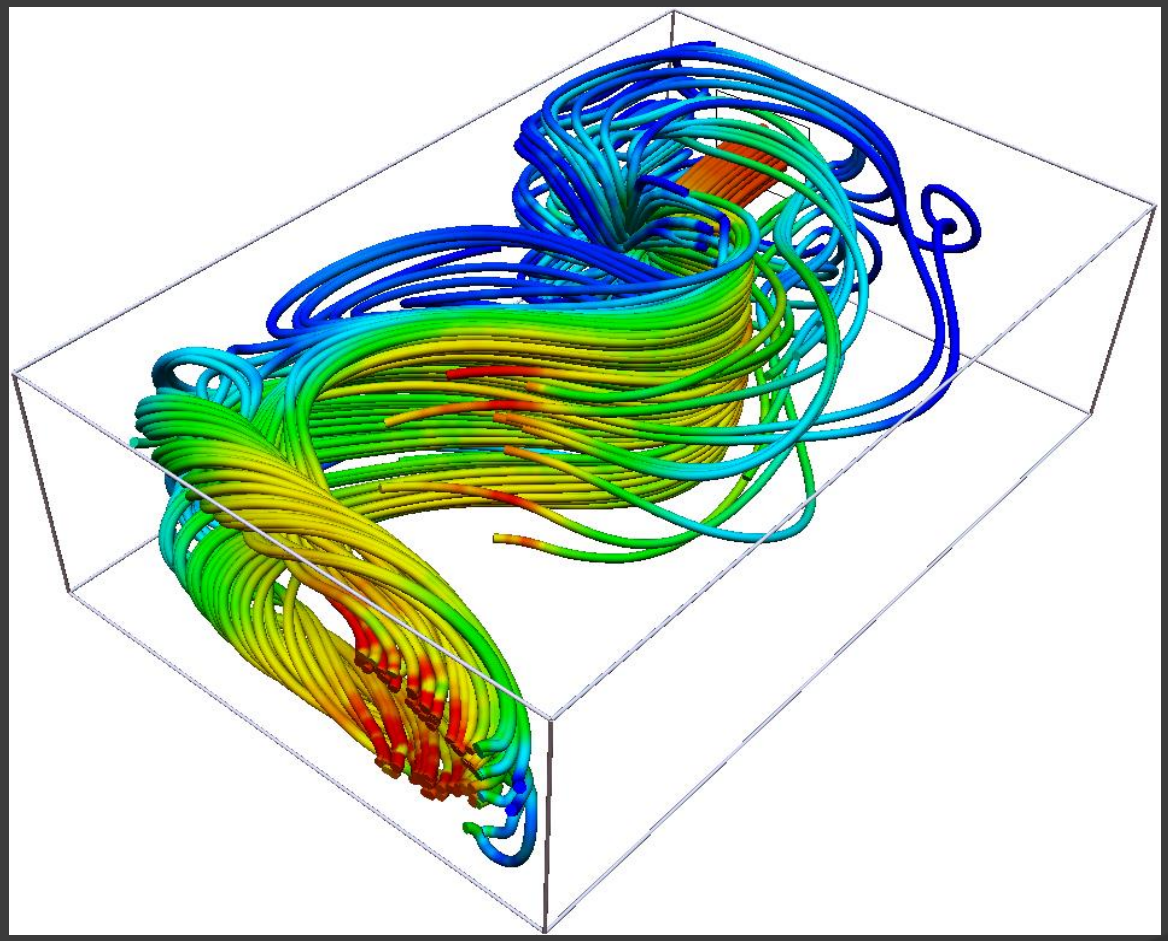


Scalar Visualization



Height plot and Isolines

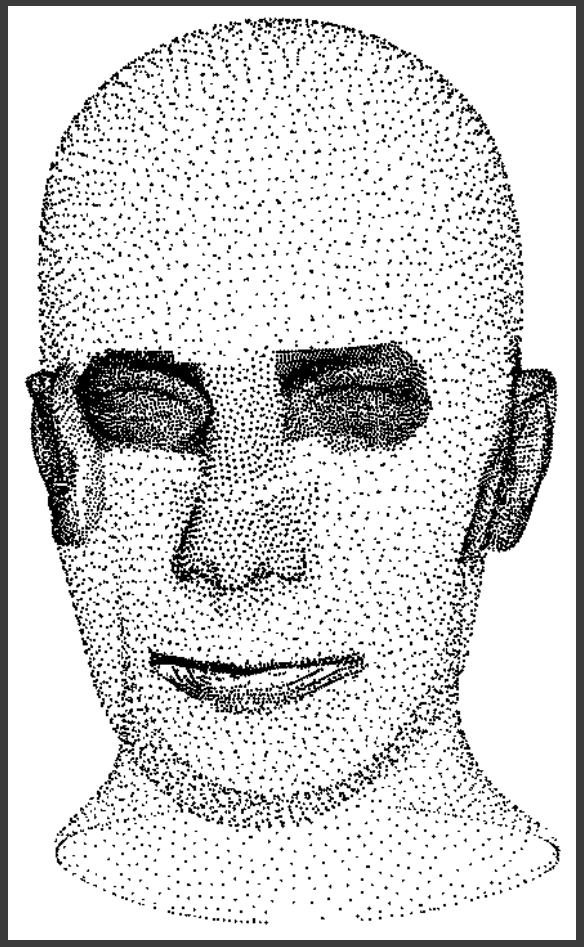
Vector Visualization

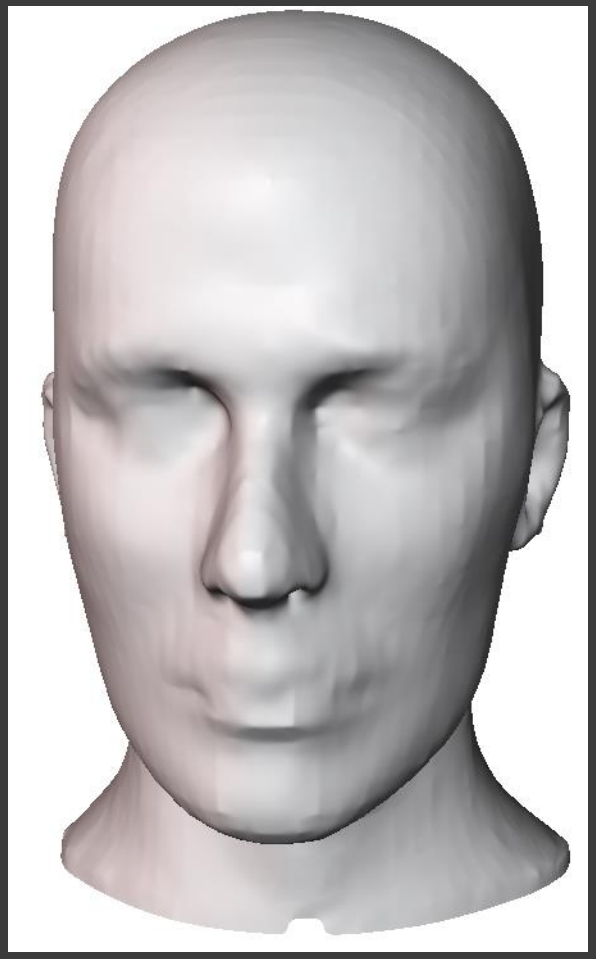


Stream Tubes

Flow Visualization

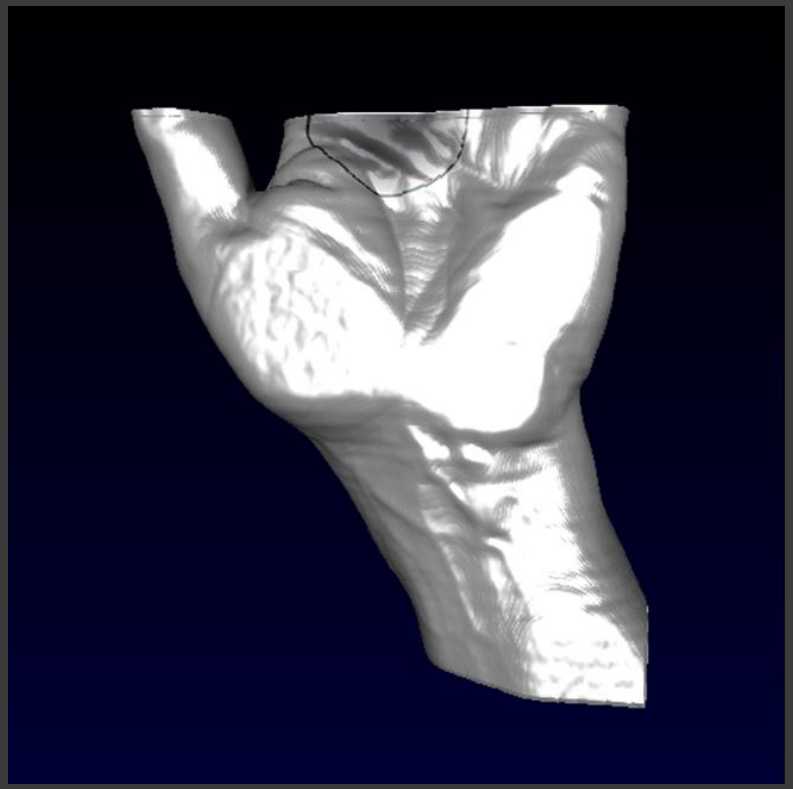
Domain Modeling



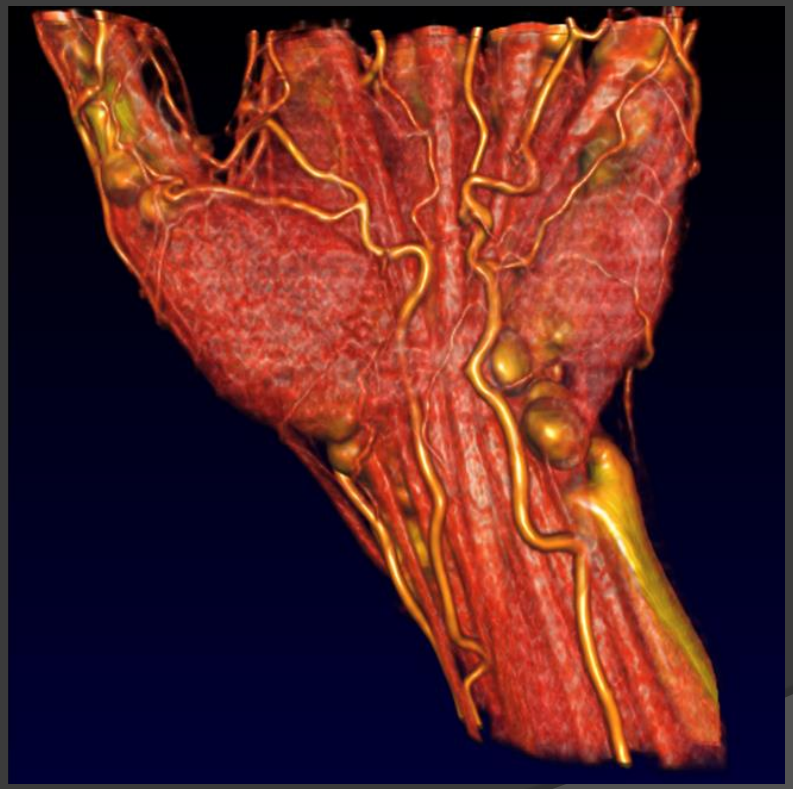


Scattered Point Cloud and Surface Reconstruction

Volume(scalar) Visualization



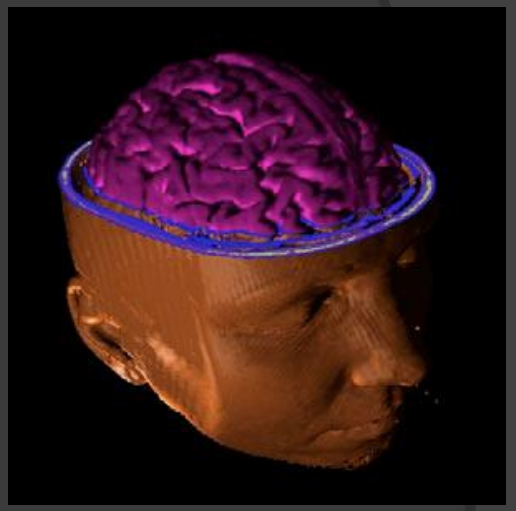
surface extraction



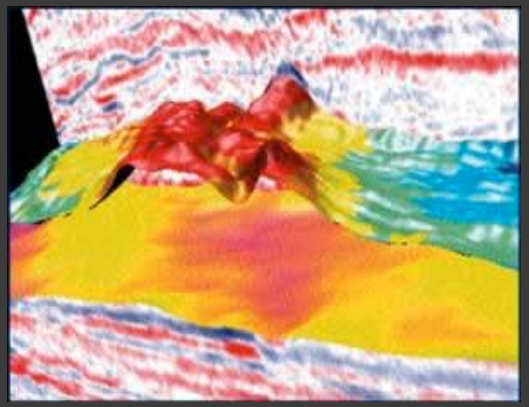
direct volume rendering

Volume data in different applications

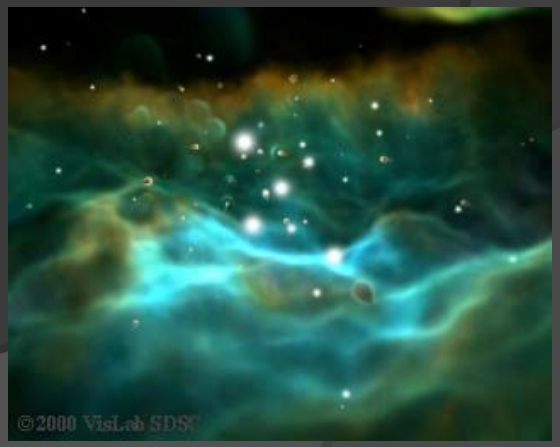
Medical data === >
(human head, blood-vessels, …)



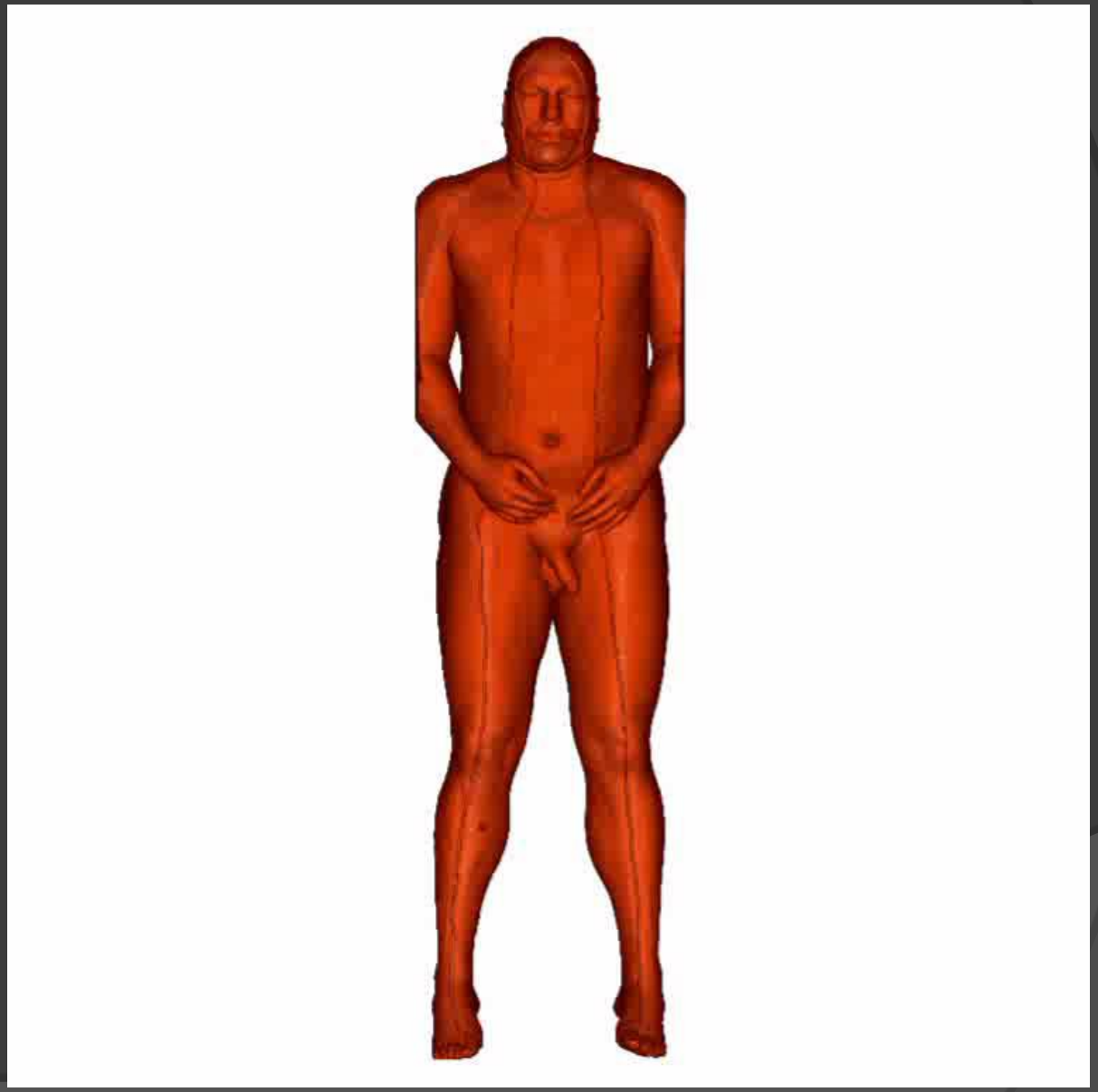
seismic data ==>



astronomy / astrophysics ===>

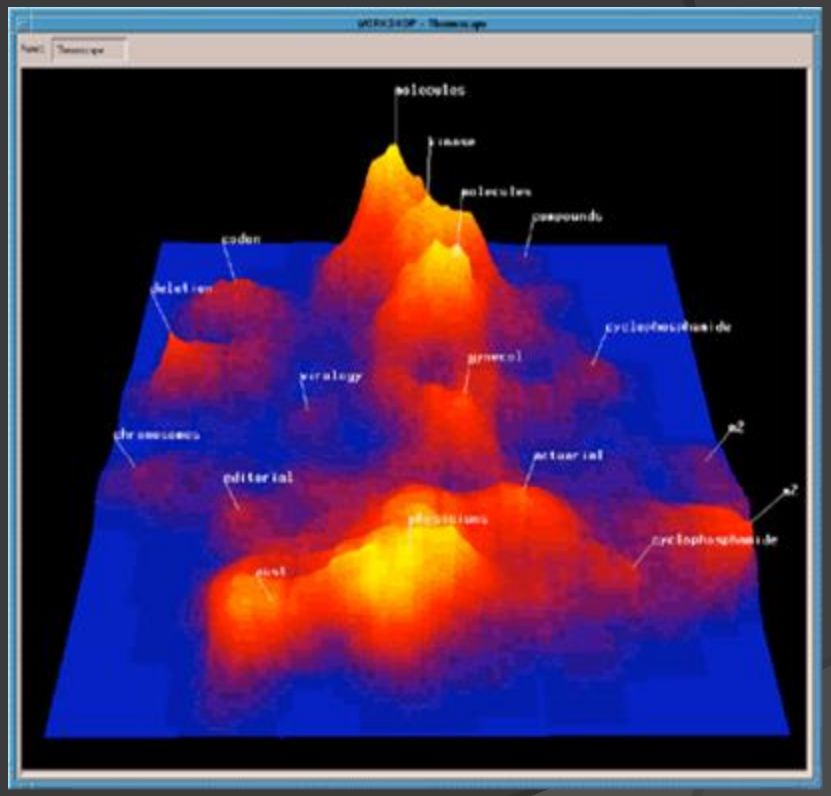


Visible human

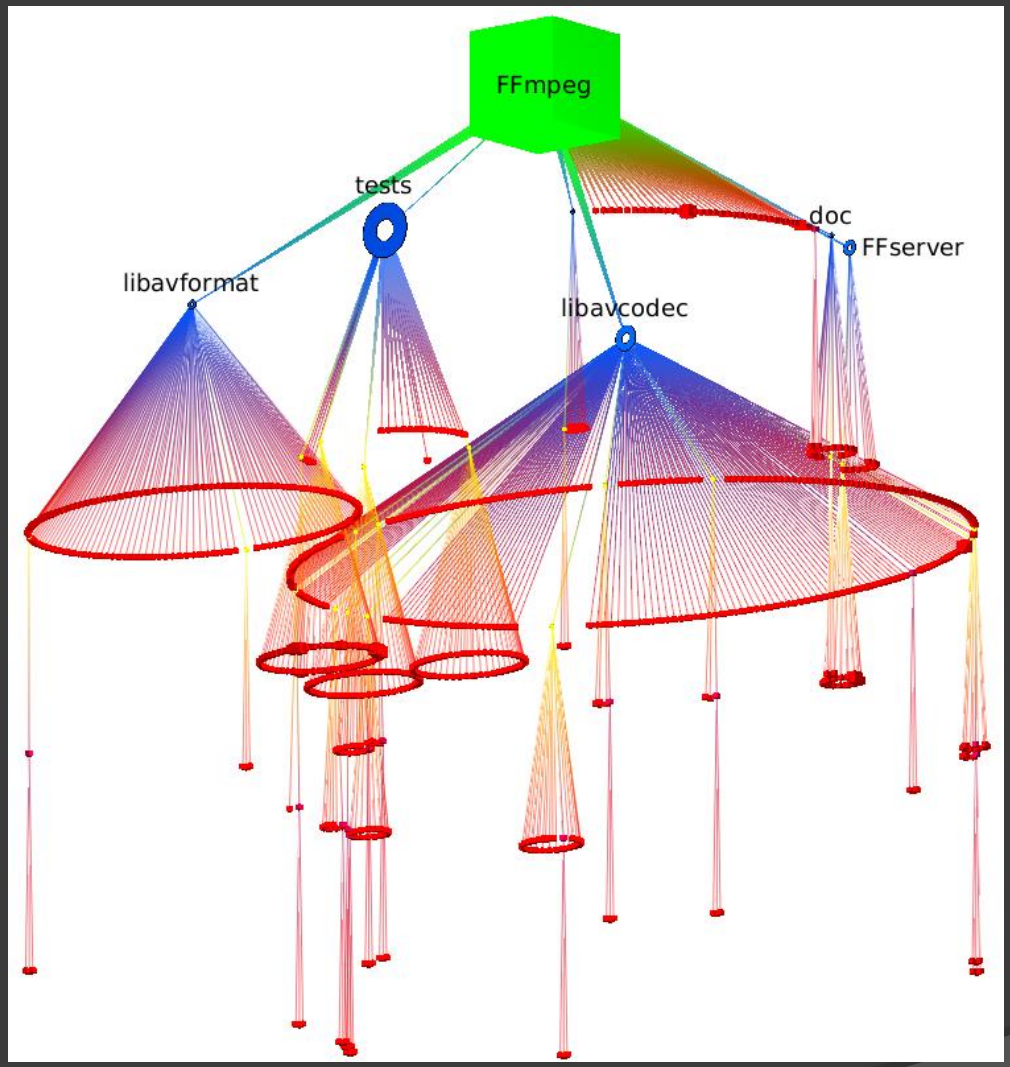


Information Visualization

- data and information from large data bases, networks, etc:
  - many sources
  - numerical, text,
  - images, multimedia, …
  - discrete, heterogeneous

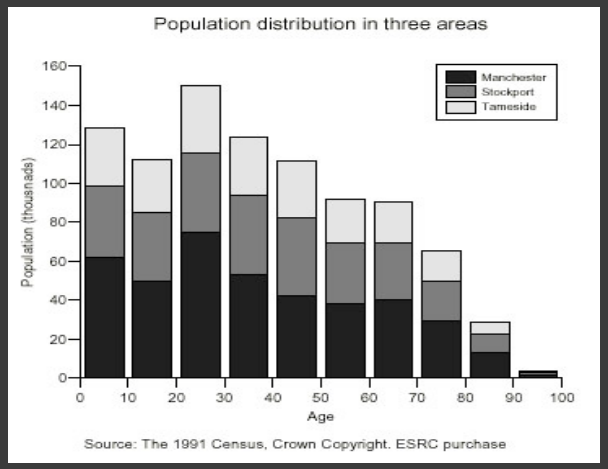


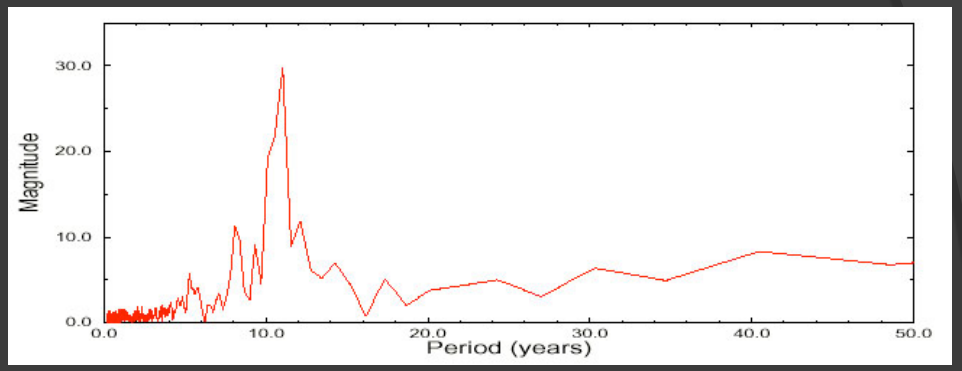
Information Visualization

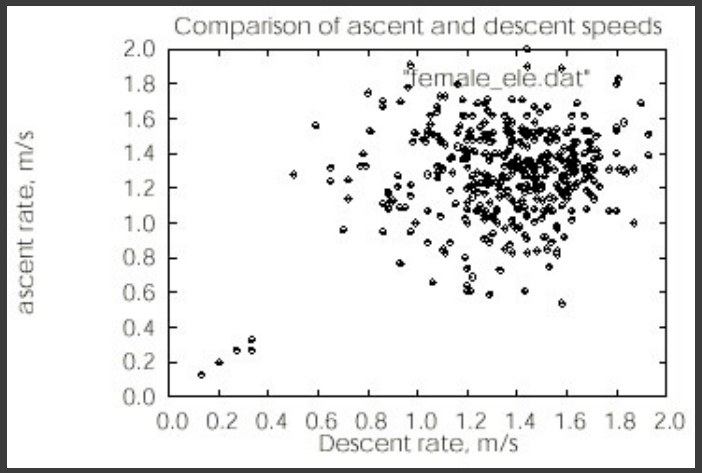


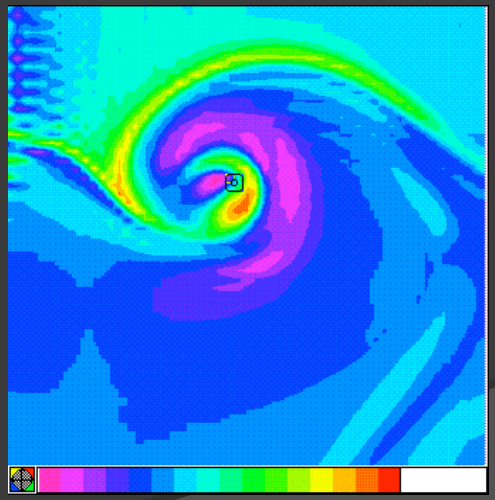
Cone-tree Layout of File Hierarchy (P. 403)

Examples: 2D graphs and charts



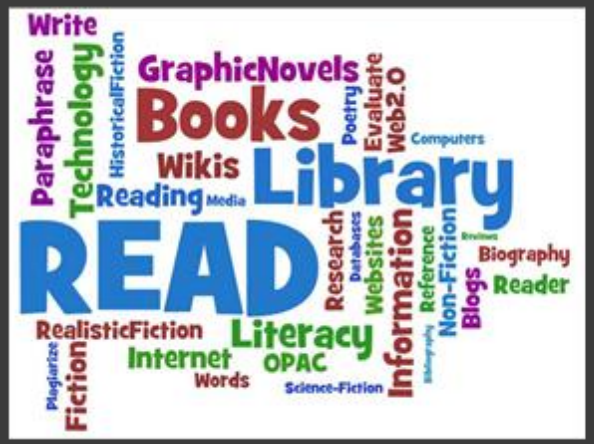






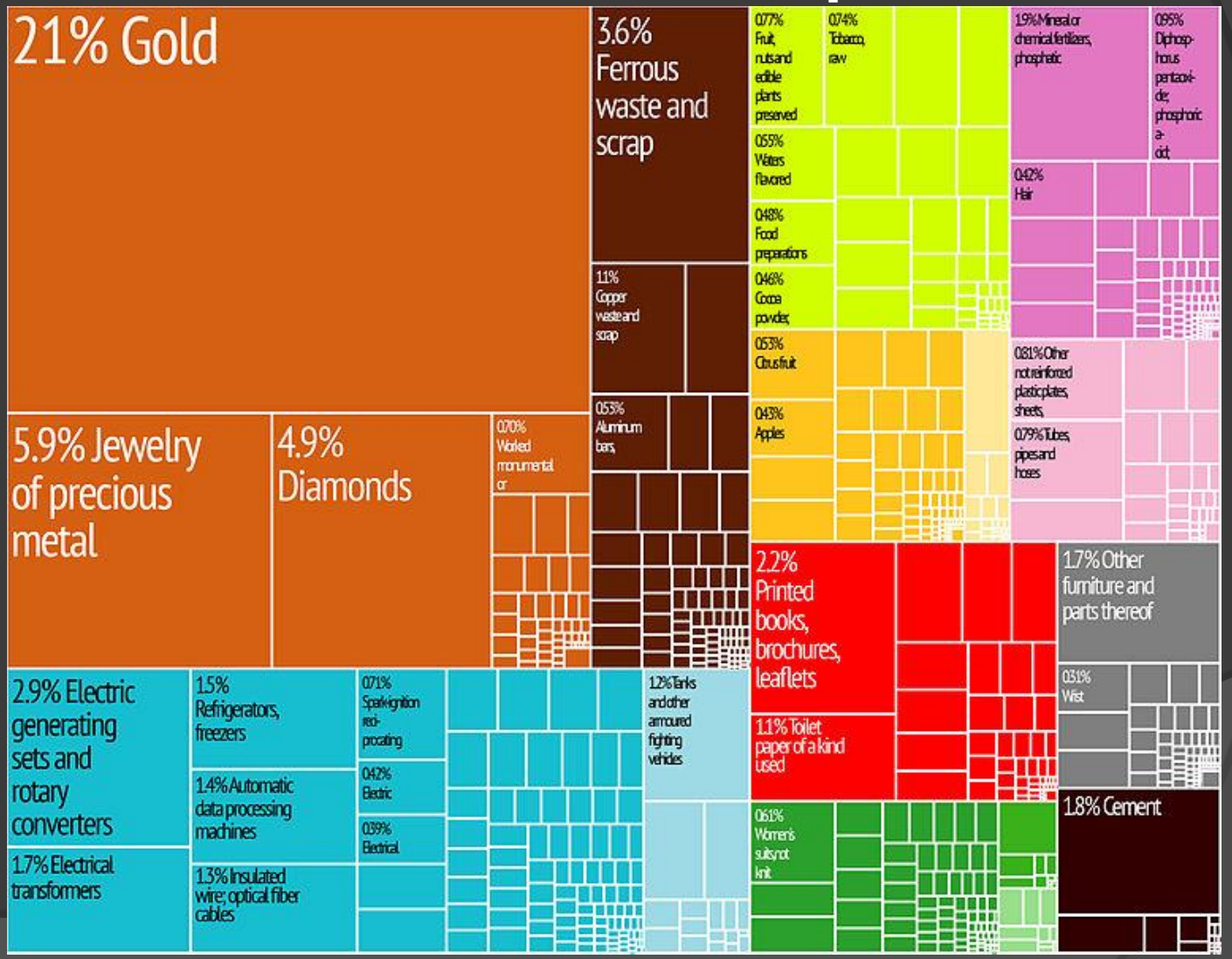
geographic data visualization

Text visualization

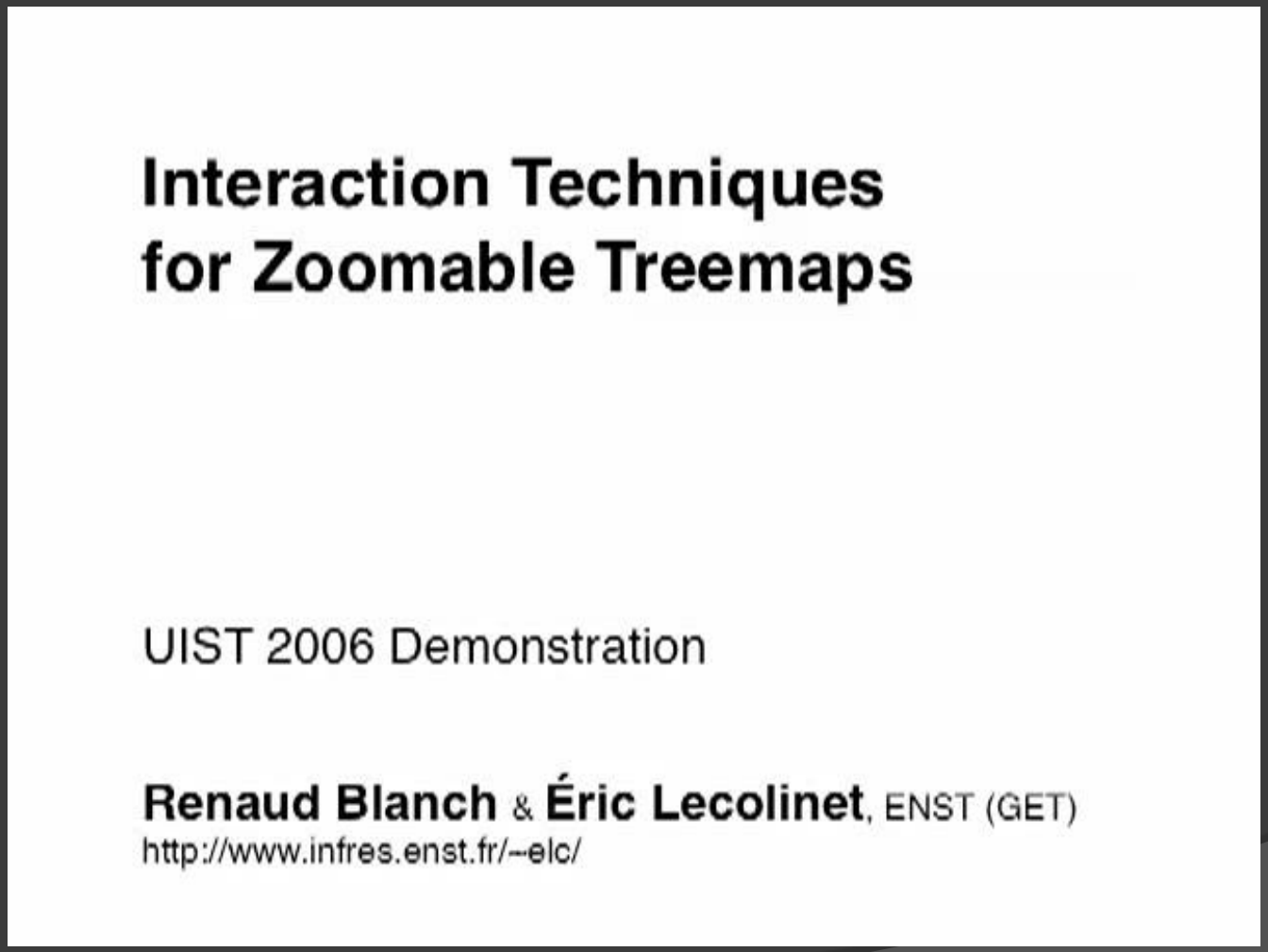


Wordles

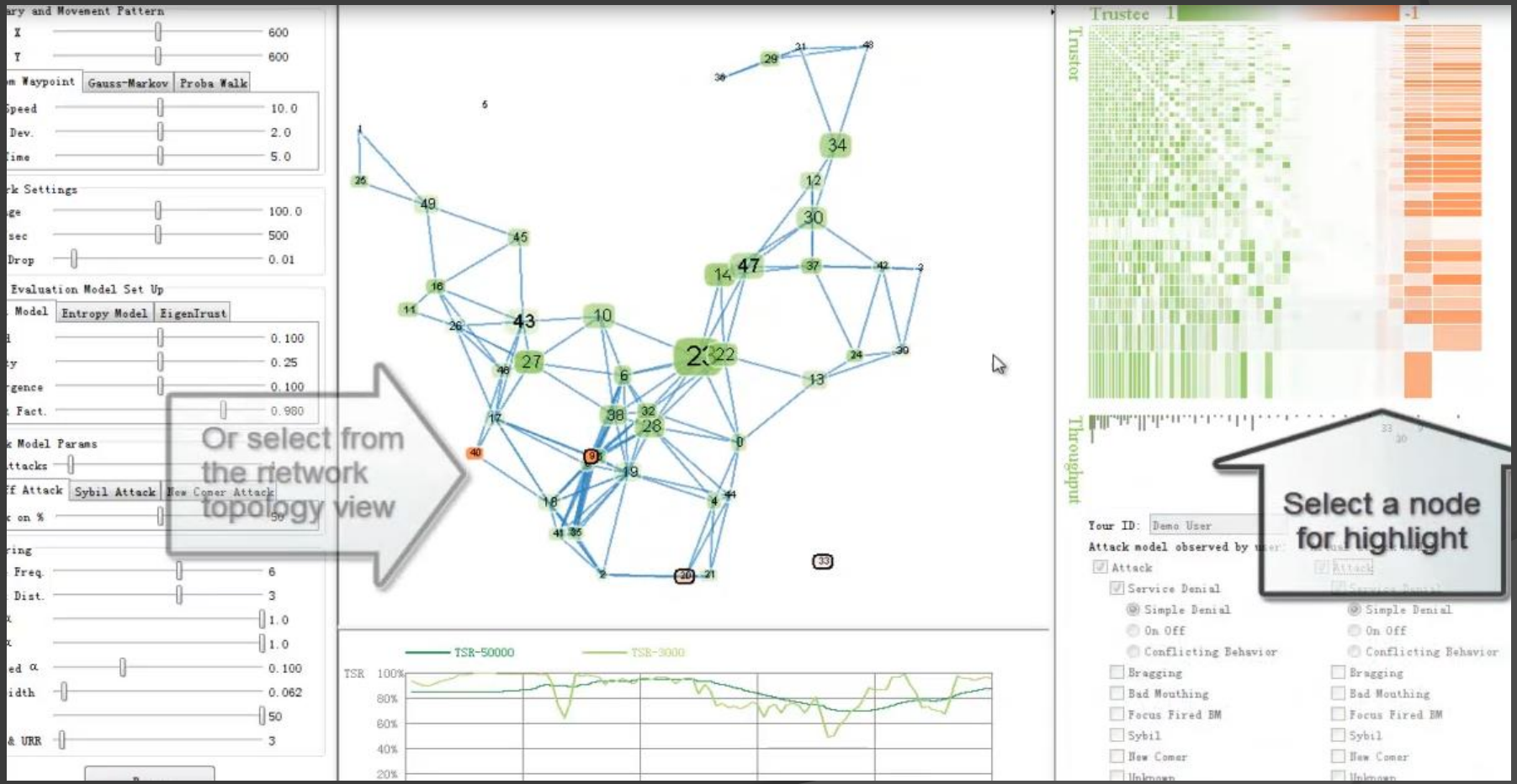
Hierarchical data visualization: Treemap



Treemap


Interaction Techniques
for Zoomable Treemaps
UIST 2006 Demonstration
Renaud Blanch & Éric Lecolinet, ENST (GET)
http://www.infres.enst.fr/~elc/

Visual Analytics



Well known Journal & conf. on Visualization

- **IEEE Visualization (**annual conf.,USA, 22st in 2011**)**
- **InfoVis (**annual conf. with IEEE Vis, 17th in 2011**)**
- **IEEE Virtual Reality (IEEE VR)**
- **IEEE Pacific Visualization (**Annual conf**. 4rd in 2011)**
- **IEEE Transactions on Visualization and Computer Graphics (TVCG)**
- **IEEE Computer Graphics & Applications (IEEE CG&A)**
- **ACM Trans. on Graphics**