

Visualization

www.cehwiedel.com

PV251

Autumn 2024

Lectures:

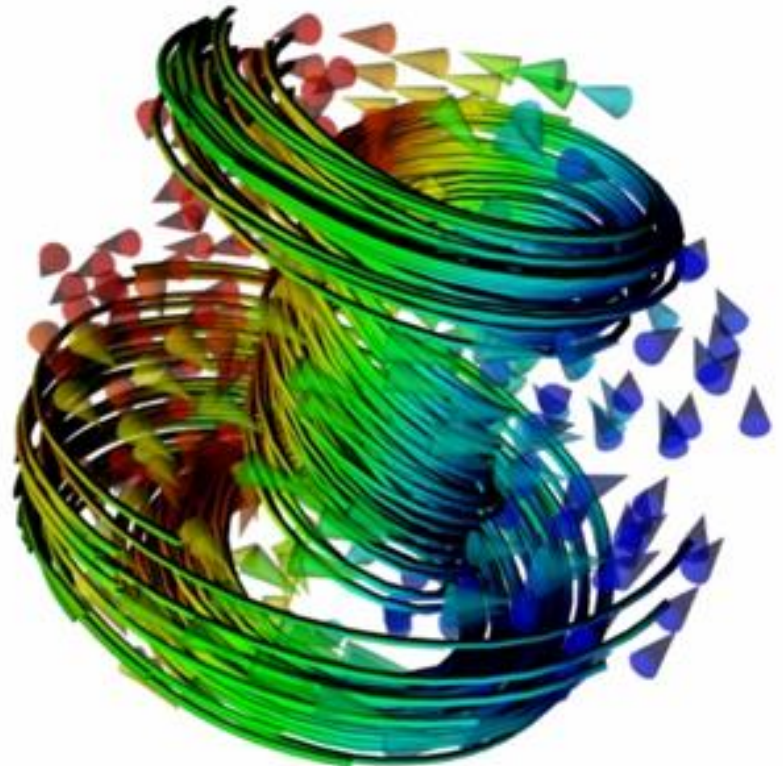
Bára Kozlíková

kozlikova@fi.muni.cz

Seminars:

Katka Furmanová

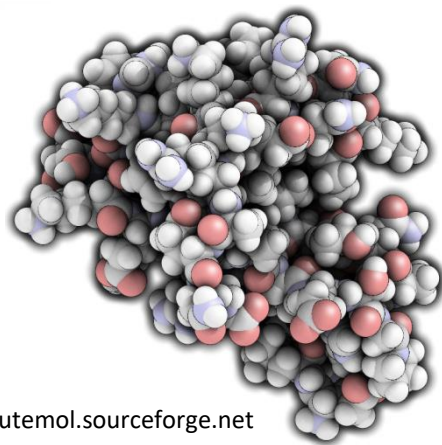
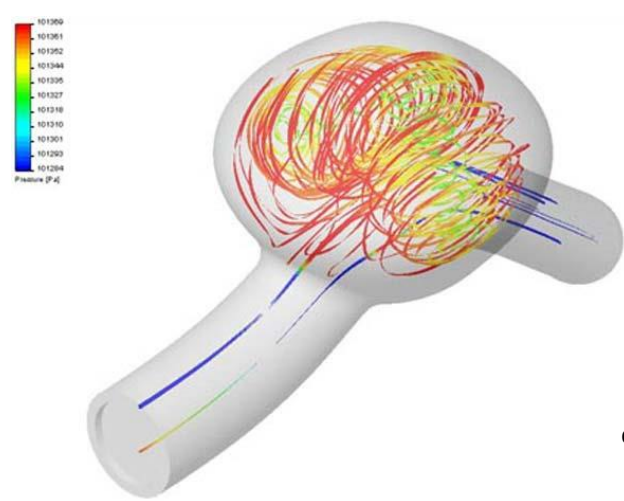
furmanova@mail.muni.cz



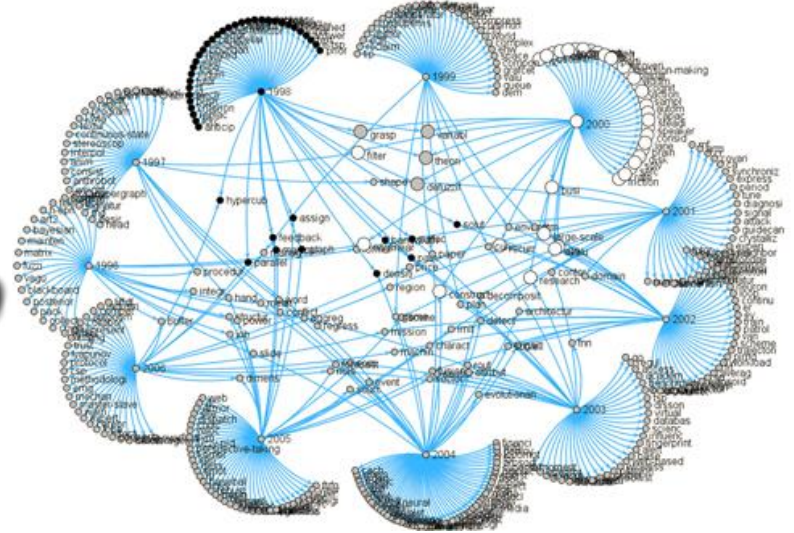
code.enthought.com

Course organization

- Lectures every Thursday at 8 AM (D1)
- Seminars bi-weekly (mandatory)
 - Who didn't enroll to a seminar group yet and they are full, please contact Katka immediately
- Grading
 - Semestral project
 - Written final exam
 - Details can be found in the Interactive syllabus in IS



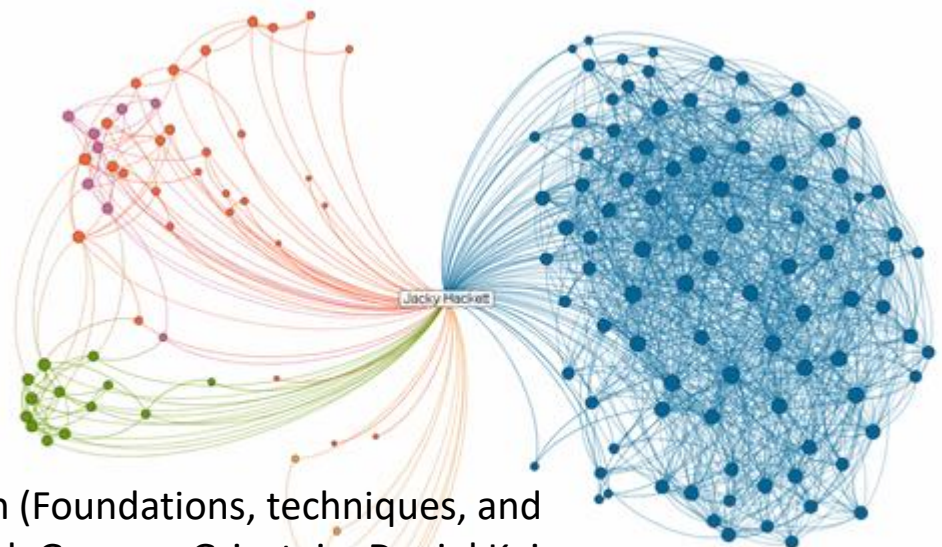
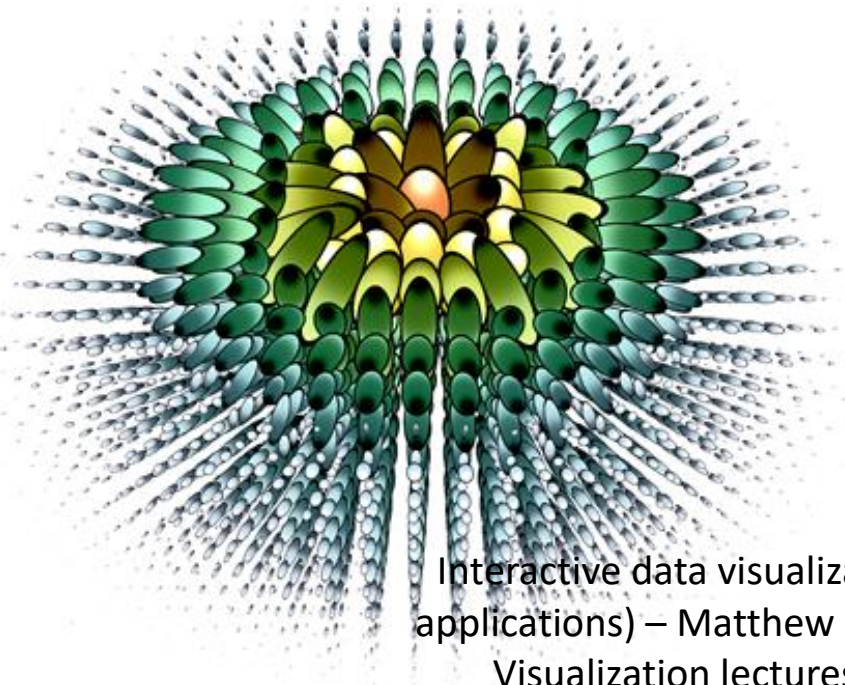
qutemol.sourceforge.net



www.flometrics.com

informationandvisualization.de

1. Introduction to Visualization



Interactive data visualization (Foundations, techniques, and applications) – Matthew Ward, Georges Grinstein, Daniel Keim

Visualization lectures – Eduard Gröller, Helwig Hauser

Visualization Analysis and Design – Tamara Munzner

www.jackyhackett.com

visservices.sdsc.edu

What is visualization?

- Conveying the information using a graphical representation



What is visualization?

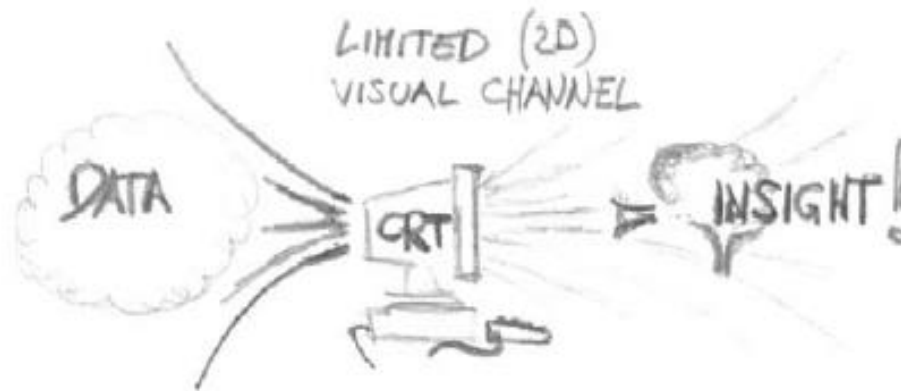
- „Transformation of symbolic into geometric“
[McCormick et al., 1987]
- „... finding the artificial memory that best supports our natural means of perception.“
[Bertin, 1967]
- „The use of computer-generated, interactive, visual representations of data to amplify cognition.“
[Card, Mackinlay, Shneiderman, 1999]

What is visualization?

- „The purpose of computing is **insight**, not numbers“ [R. Hamming, 1962]
- „...to form a mental vision, image, or picture of something not visible or present to the sight, or of an abstraction; to make visible to the mind of imagination“ [Oxford Engl. Dict., 1989]

What is visualization?

- **Tool** to enable a **User** insight into **Data**



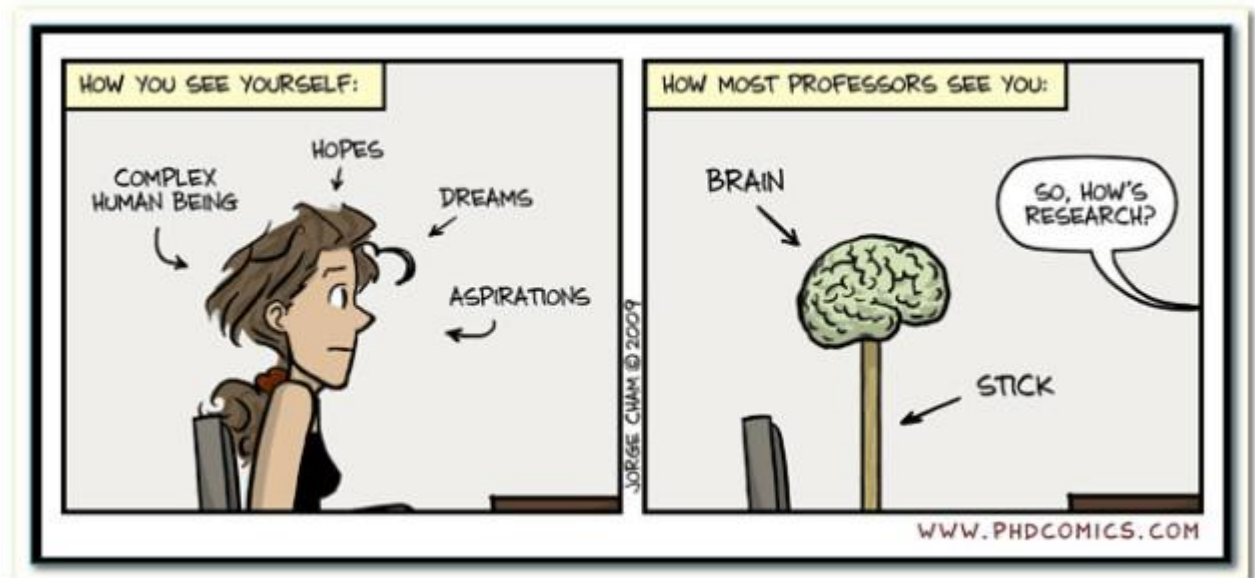
- Computer Graphics, but not photorealistic rendering

Content of the course

- Visualization and interaction techniques
- Data types and their representation
- Comparison of visualization techniques
- Human cognition and processing of information
- Design of efficient visualizations
- And many other topics...

Why creating visualizations?

- Decision making
- View onto data in a context
- Support for computations
- Presenting an idea
- Inspiration
- ...



Three main functions of visualization

- **Data storage**

- Photos, ...

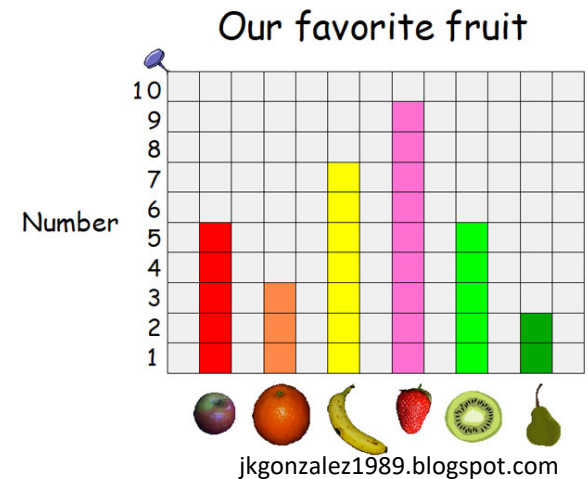


- **Analysis of information**

- Data processing, evaluation, interaction

- **Conveying the information**

- Data sharing, cooperation, highlighting important aspects of data



Why is visualization so important?

- **Sight** is one of the main senses
- We are surrounded by visualization (newspapers, maps, weather forecast, stock market, statistics, posters, advertisement, ...)
- Improving the decision process, better understanding of context of the data



Why is visualization so important?

- Anscombe's quartet

| Set A | | Set B | | Set C | | Set D | |
|-------|-------|-------|------|-------|-------|-------|------|
| 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 | 8.1 | 14 | 8.84 | 8 | 7.04 |
| 6 | 7.24 | 6 | 6.13 | 6 | 6.08 | 8 | 5.25 |
| 4 | 4.26 | 4 | 3.1 | 4 | 5.39 | 19 | 12.5 |
| 12 | 10.84 | 12 | 9.11 | 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 |

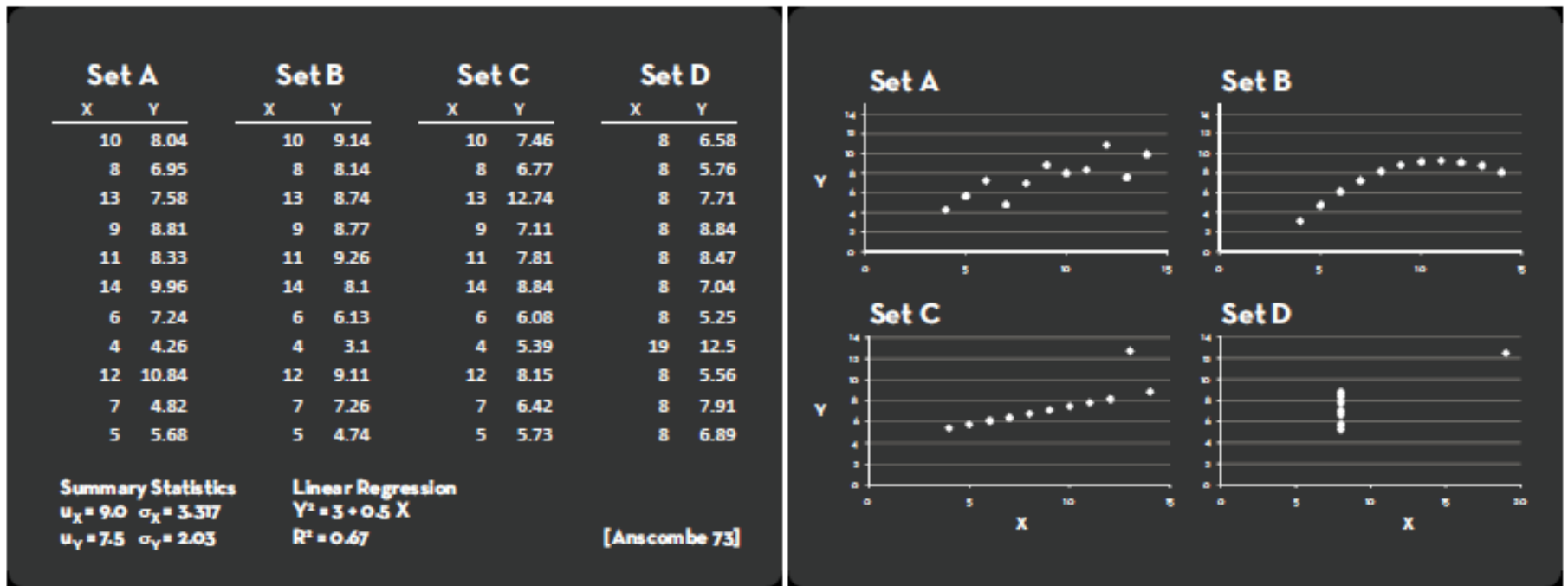
Summary Statistics
 $\mu_X = 9.0$ $\sigma_X = 3.317$
 $\mu_Y = 7.5$ $\sigma_Y = 2.03$

Linear Regression
 $Y^2 = 3 + 0.5 X$
 $R^2 = 0.67$

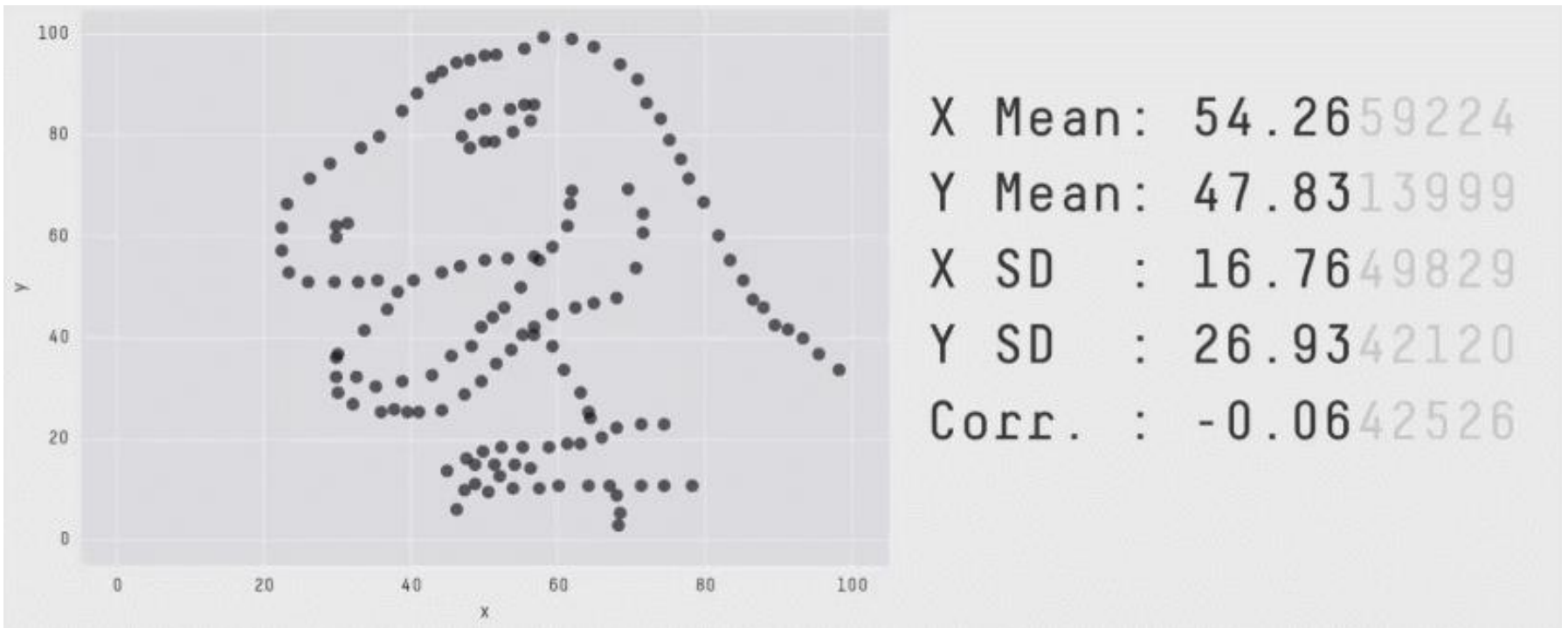
[Anscombe 73]

What is the best way to present this data?

Why is visualization so important?



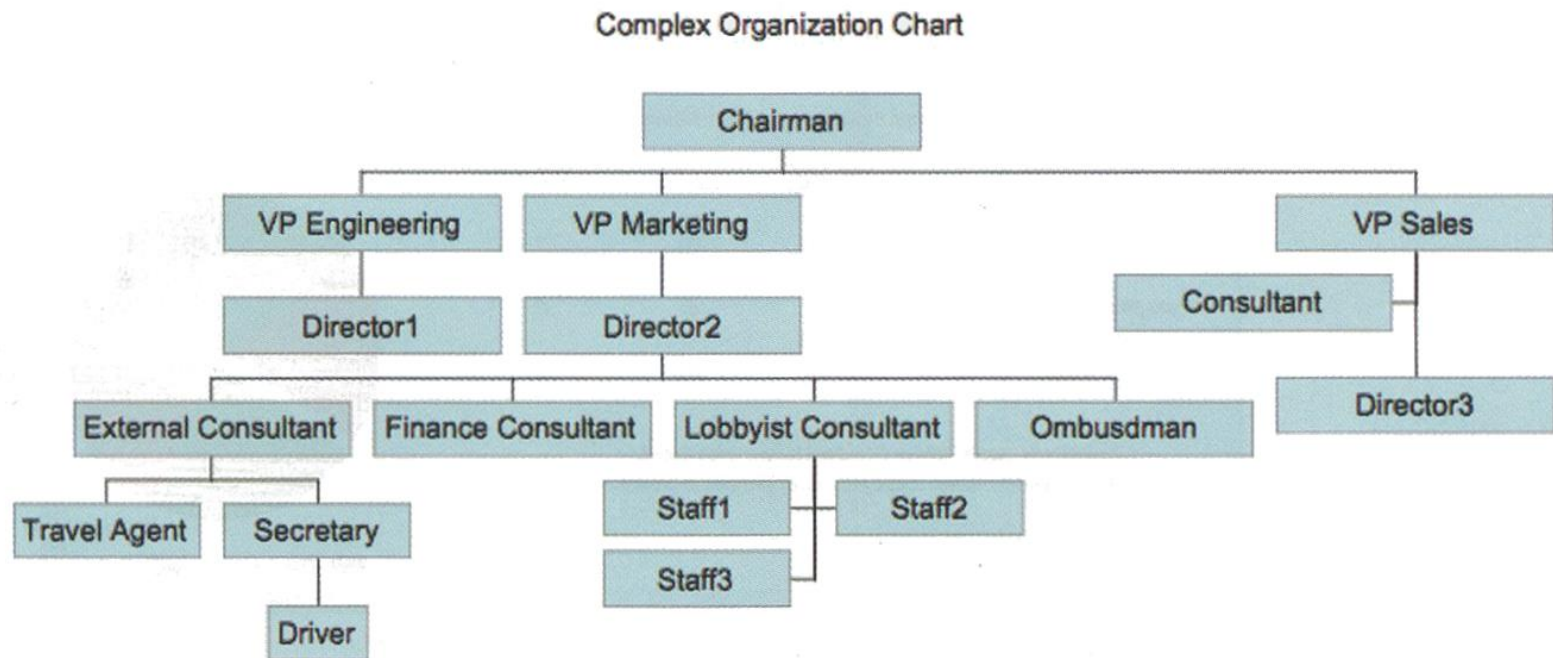
“Never trust summary statistics alone; always visualize your data”



Alberto Cairo

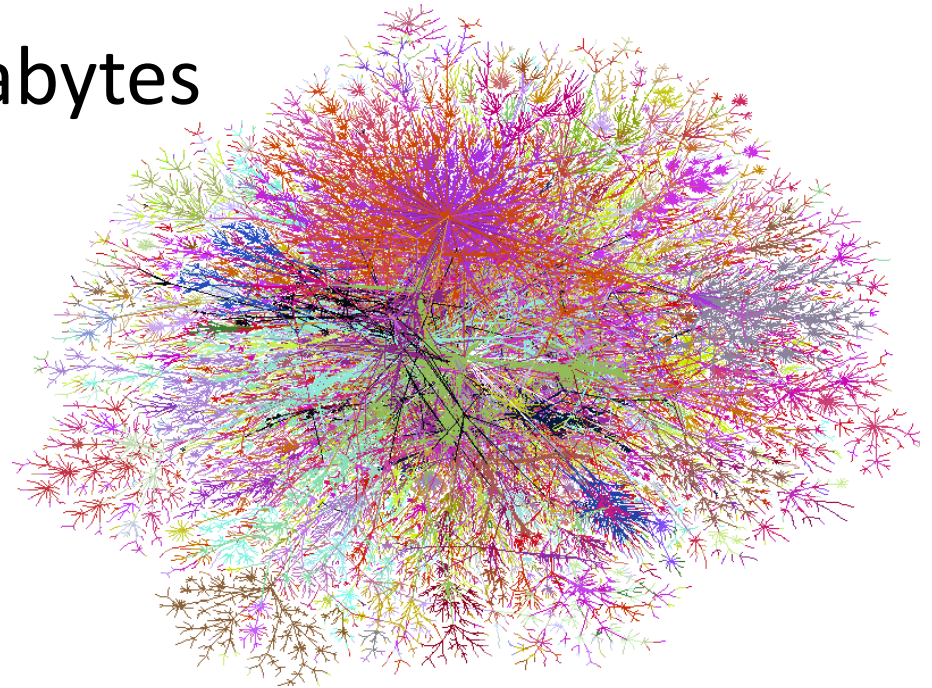
Why is visualization so important?

- Complex structures can be expressed in a simple and intuitive way

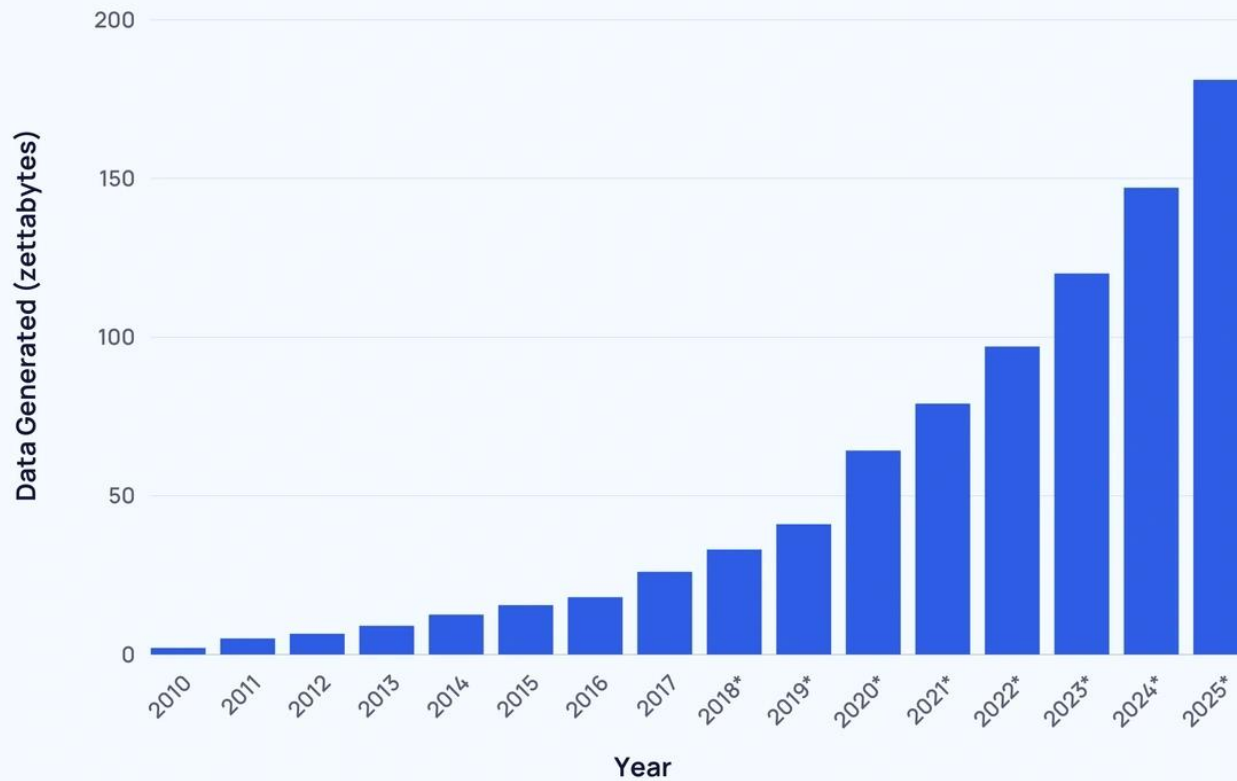


Why is visualization so important?

- In 2002 there were 5 exabytes of new information
- In 2006 it was 161 exabytes
- In 2020 it was 44 zettabytes
- Need to process such amount of data



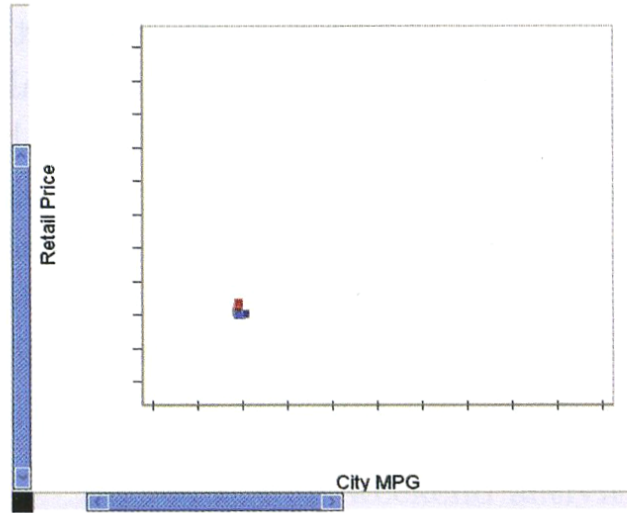
Global Data Generated Annually



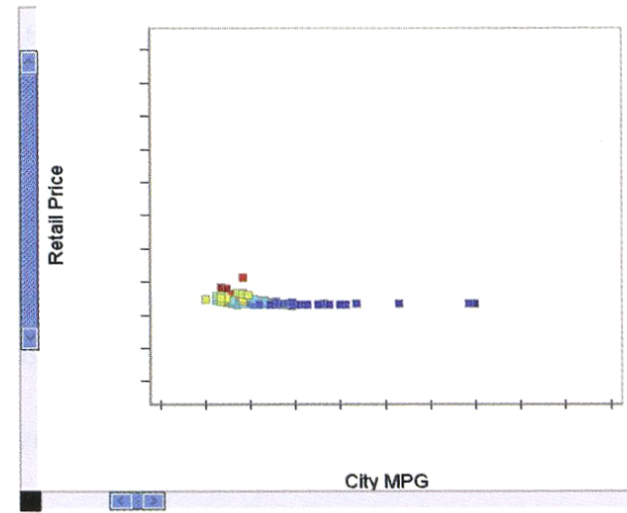
Research goals in visualization

- **Understand** how visualization conveys the information
 - What is perceived by the humans?
 - How visualization corresponds to the human mindset?
- **Design and create principles and techniques** for efficient visualization
 - Improve the cognition process
 - Strengthen the relationship between visualization and mindset

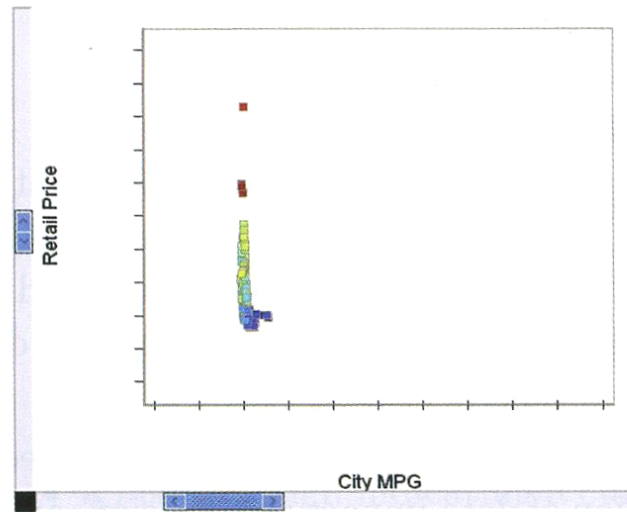
Consequences of wrong visualization



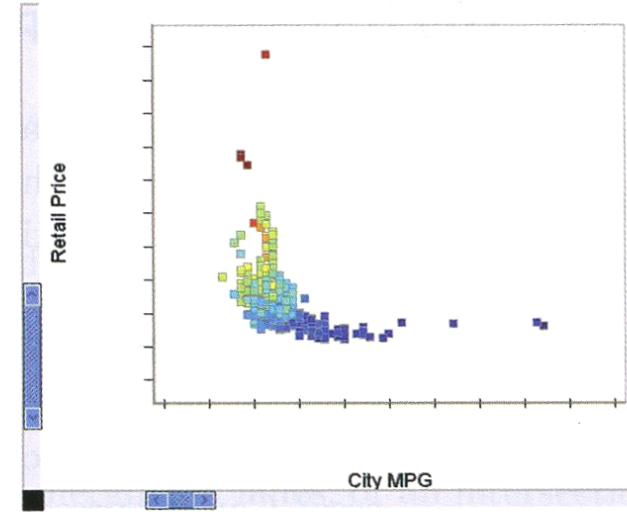
(a)



(b)



(c)



(d)



History

- Visualization is an old discipline
- First visualizations based on intuition – first graphical illustrations
- Visualization as a research discipline emerged more than 30 years ago
- First research vis conferences in 1990



History

- Image-based communication appeared much earlier than written one



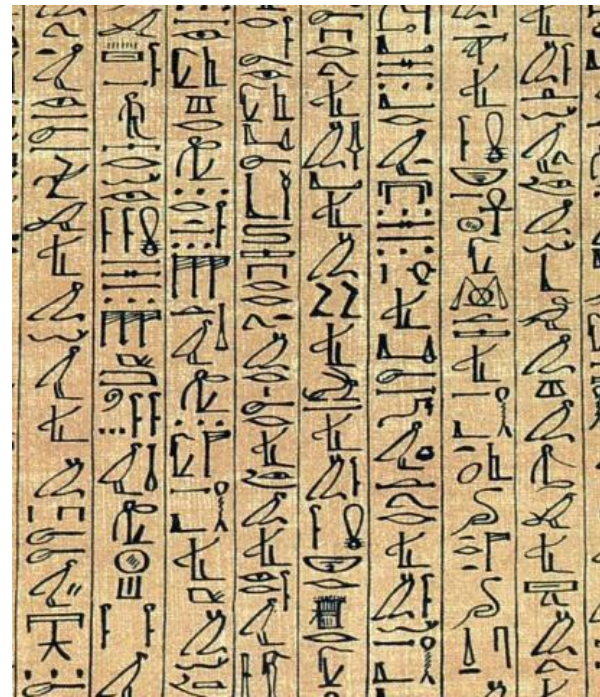
Lascaux, France, 15 000 - 13 000 B.C.

History

- Images were transferred to first systems of writing – Mesopotamia, Egypt, ...



Kish limestone tablet – the oldest written document (3500 B.C.)



Hieroglyphs (3000 B.C.)

History

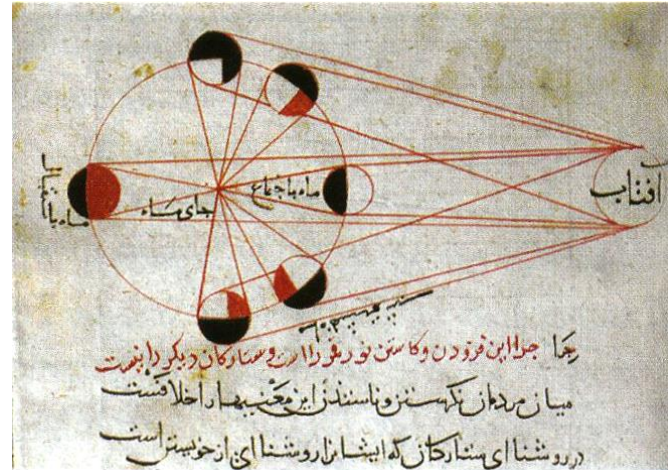
- Visualizations were created mostly because of necessity – business routes, religion, communication
- Mostly maps



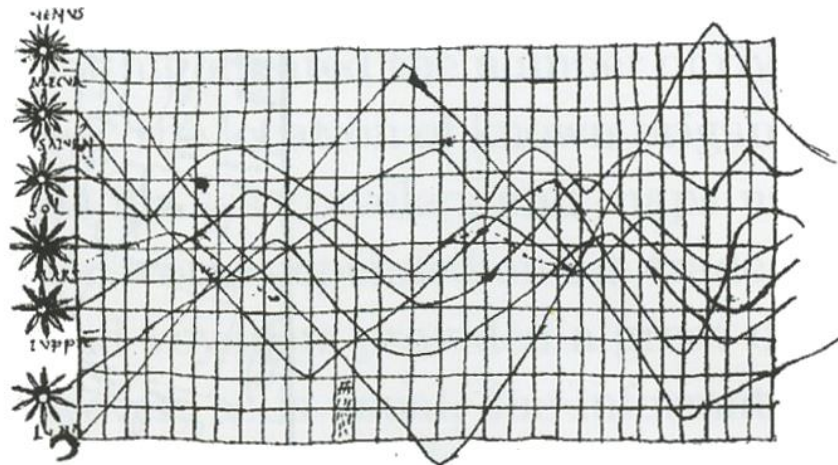
Peutinger map of Roman empire

History

- Moon phases (1030)

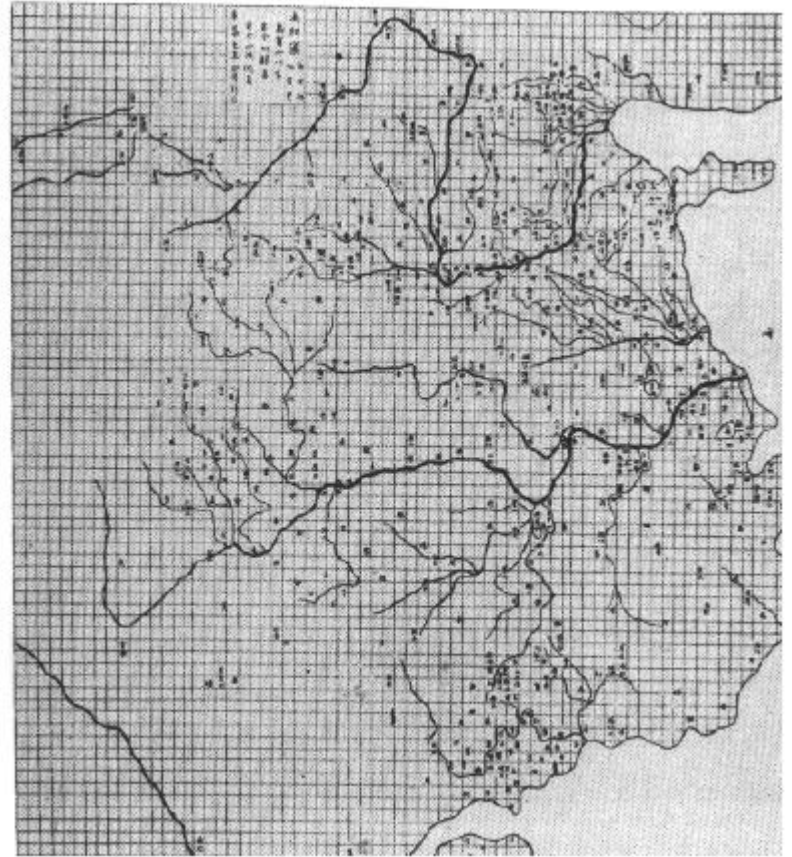


- Movement of planets

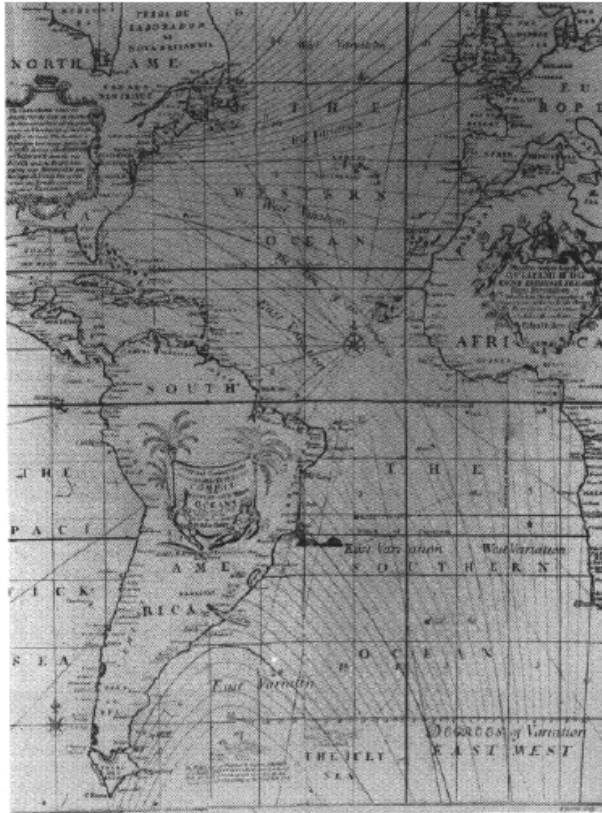


History

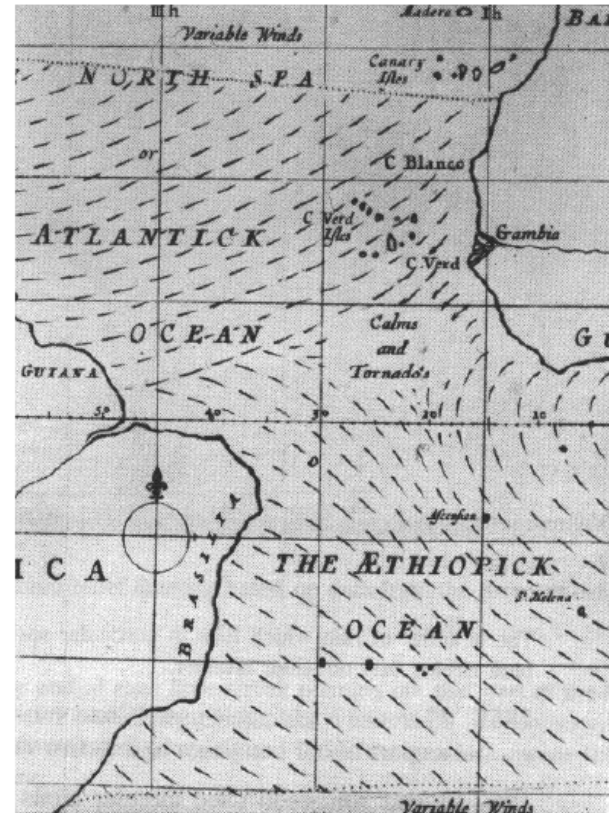
- China, 1137
- First geographic map using Cartesian coordinates
- Lattice with lines representing latitude and longitude



History – cartography



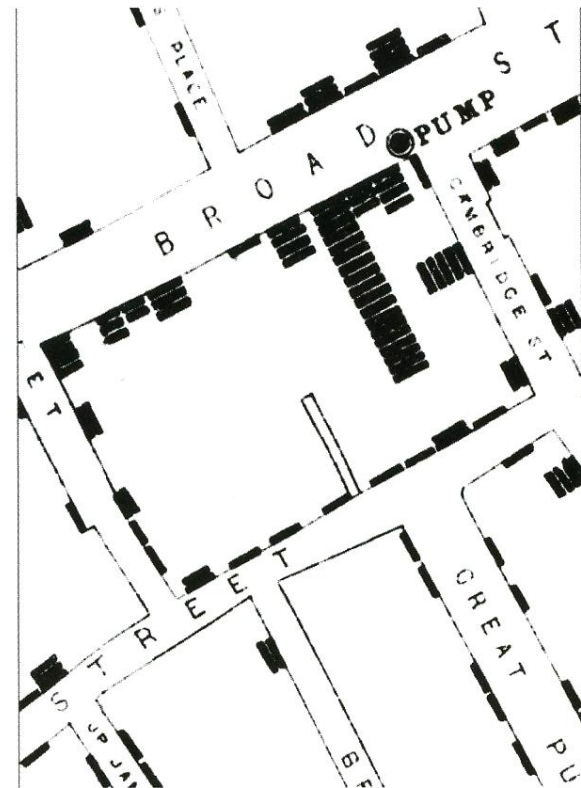
Isolines showing the deviations of compass



Visualization of winds

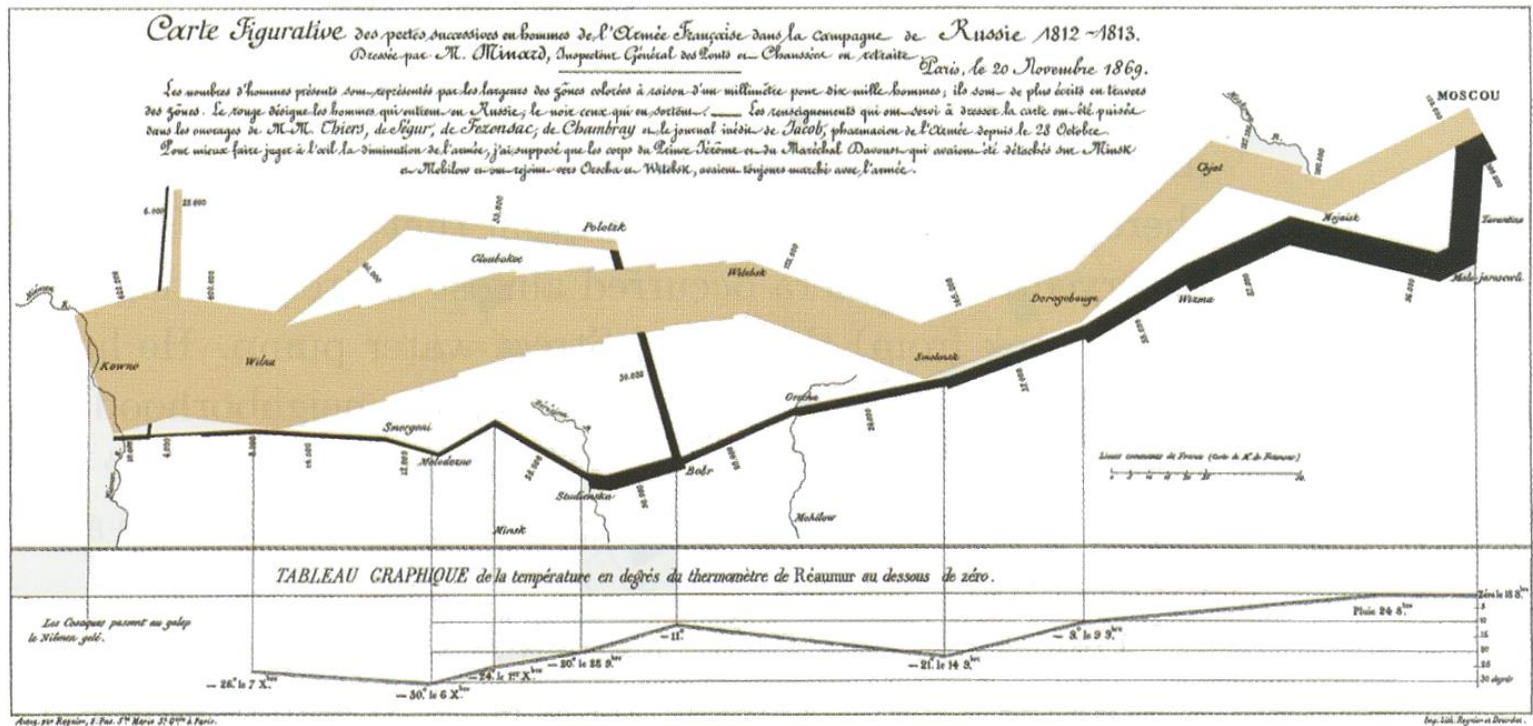
History

- In 1854 in London, during the cholera epidemic, visualization helped to reveal the source of infection
- <http://www.imdb.com/title/tt2061801/>
- John Snow - On the Mode of Communication of Cholera
- http://en.wikipedia.org/wiki/The_Ghost_Map



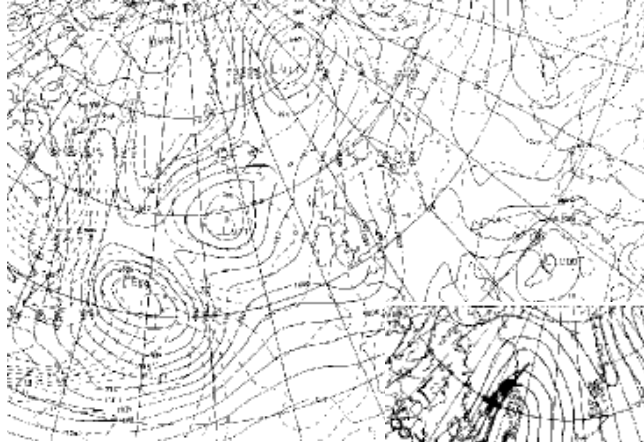
History

- Napoleon's invasion of Moscow – highlighting the losses

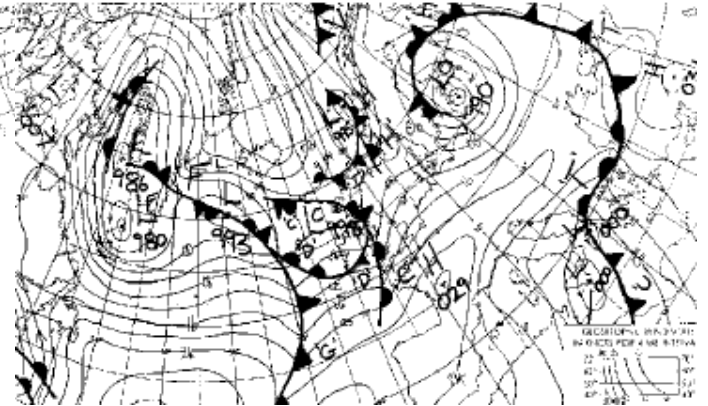


Meteorology

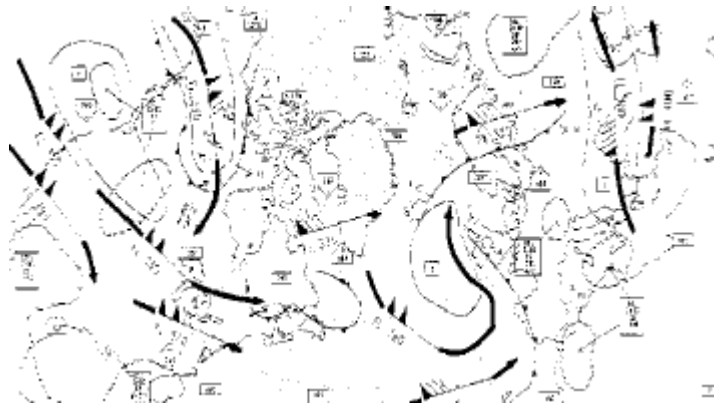
Visualization of
air pressure



Front visualization

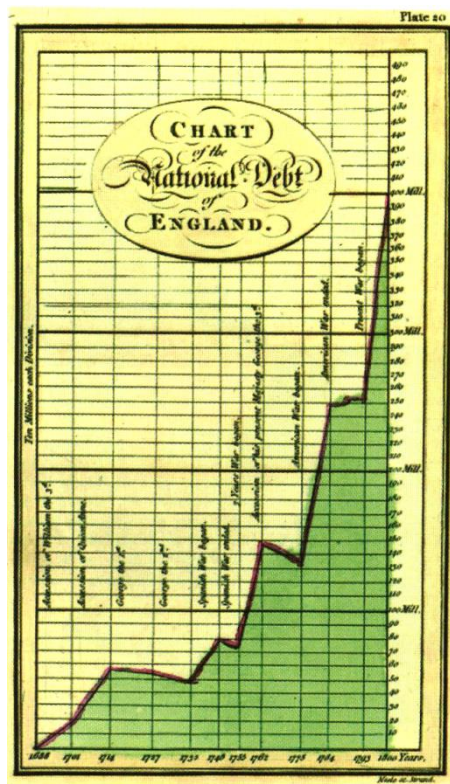


Maps for pilots

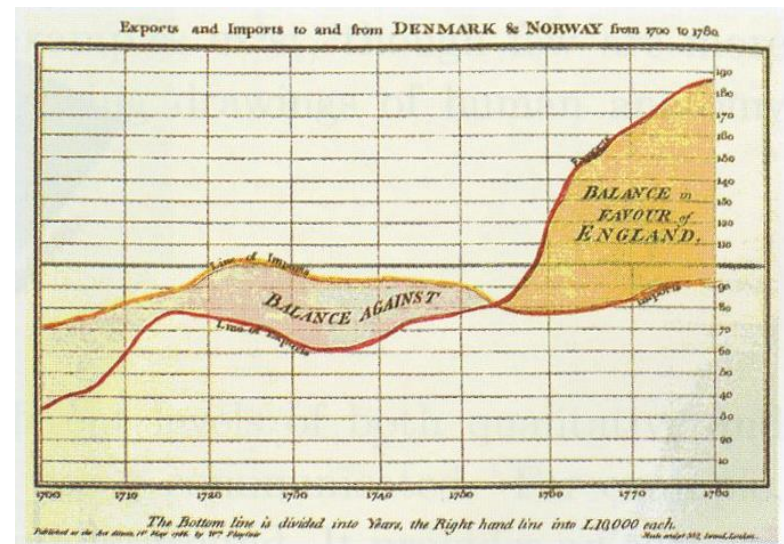


Business visualization

- Using two axes



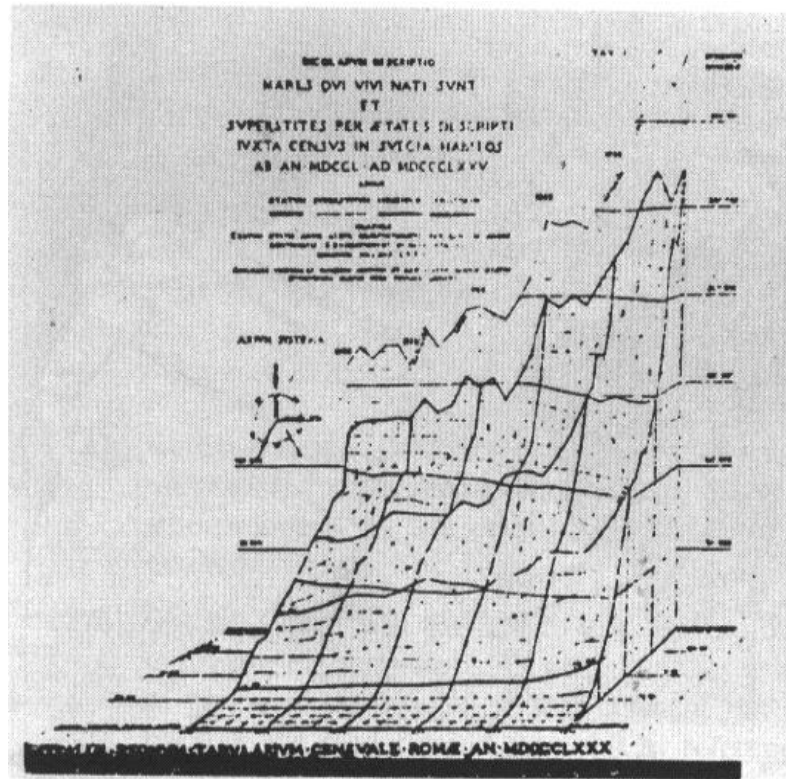
National debt of England
(William Playfair)



Business development between England
and Norway and Denmark (1786)

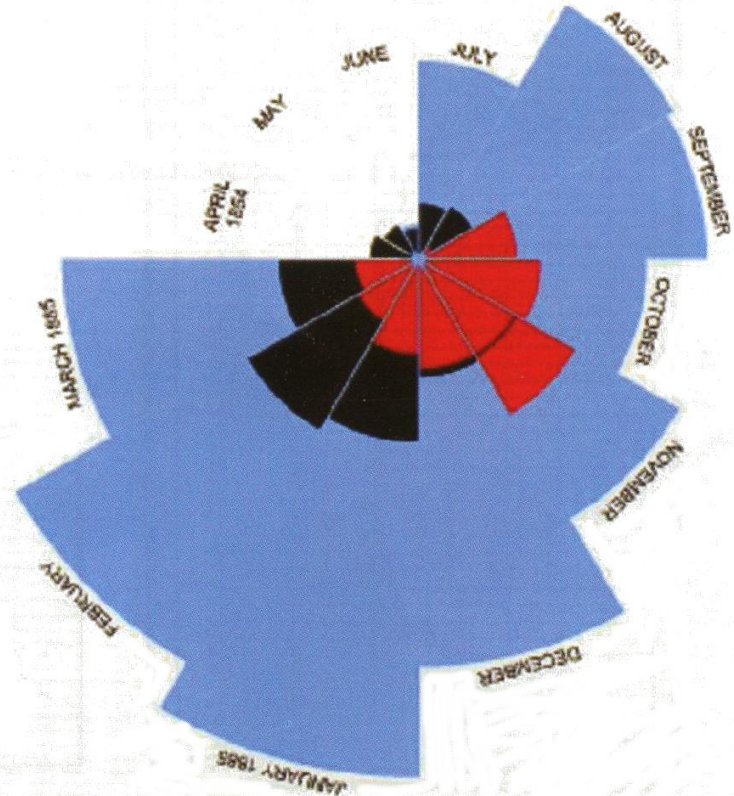
Population development

- Population size in Sweden 1750 – 1785
- Axes represent year and age category



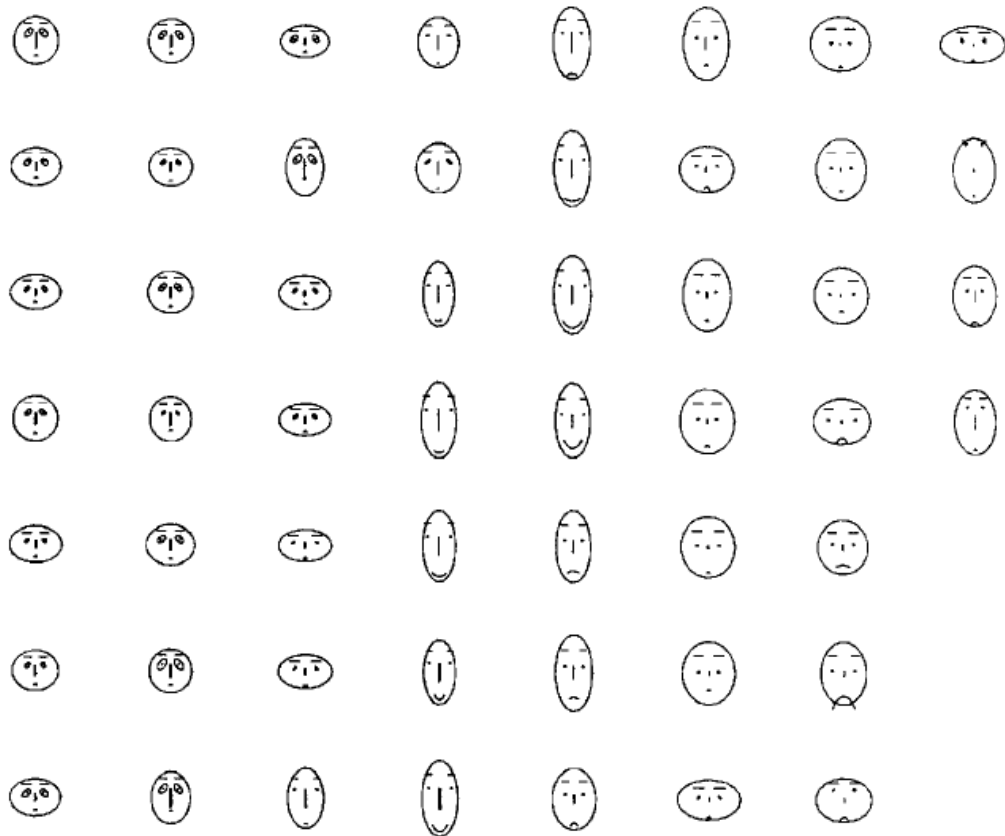
History

- Graph shows the mortality in army between 04/1854 and 05/1855 (Florence Nightingale)
- Blue – sickness
- Red – injury
- Black - other



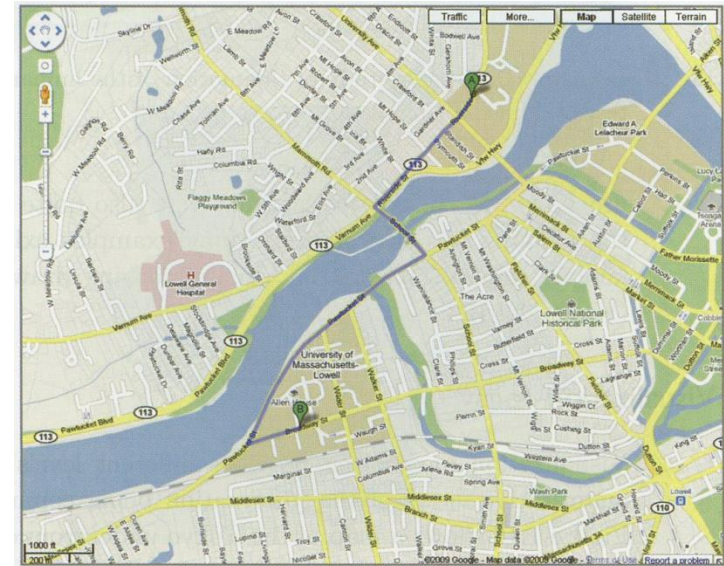
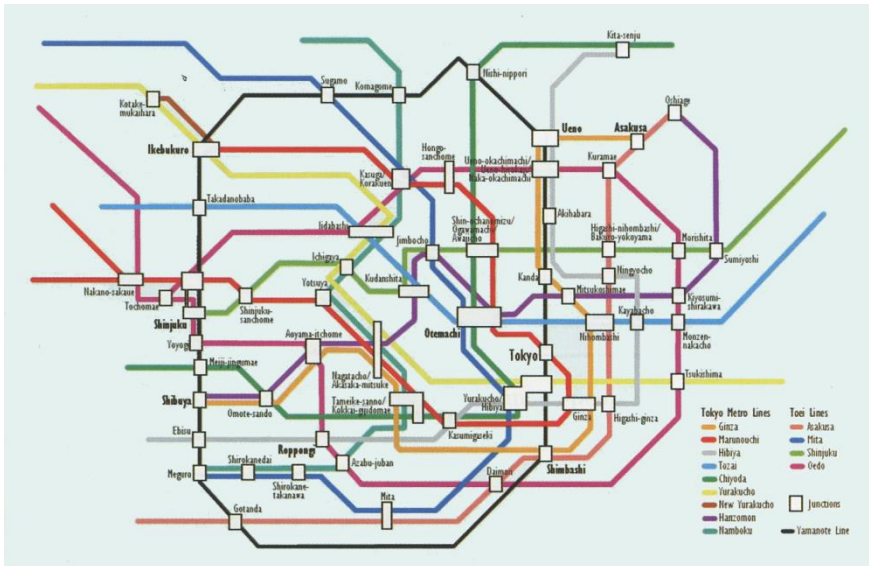
Visualization „today“

- Chernoff faces, 1973
 - Data properties encoded into geometric facial features



Visualization today

- Visualization enables different views onto data
 - from the qualitative and quantitative point of view
- Example – metro map vs. street map



Visualization today

- Data can be visualized precisely

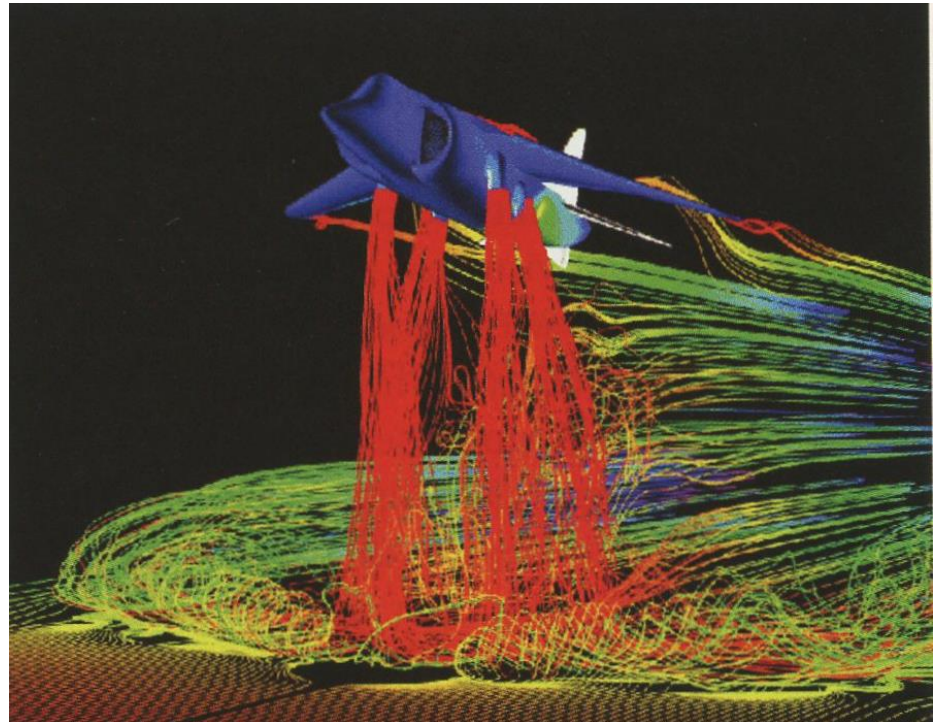
\$11,956,584,748,608.58

- Fast identification of problem



Visualization today

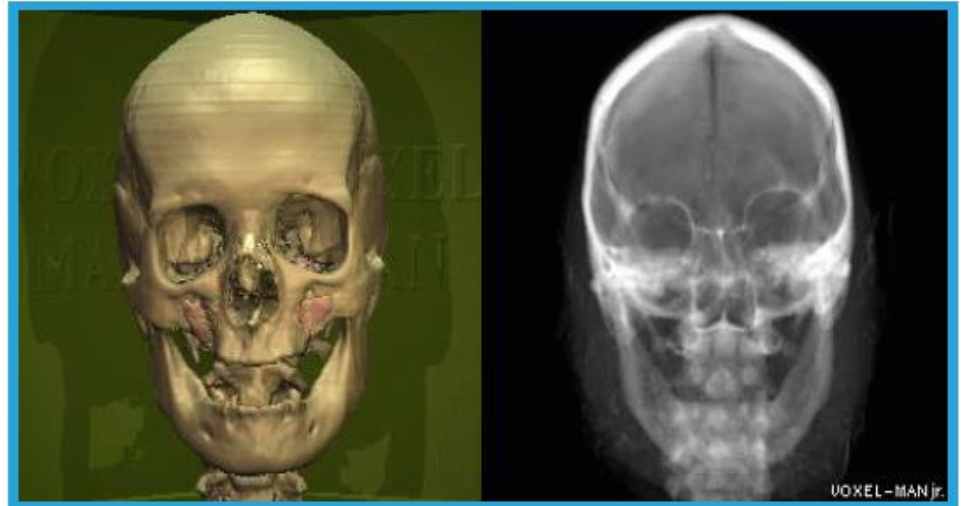
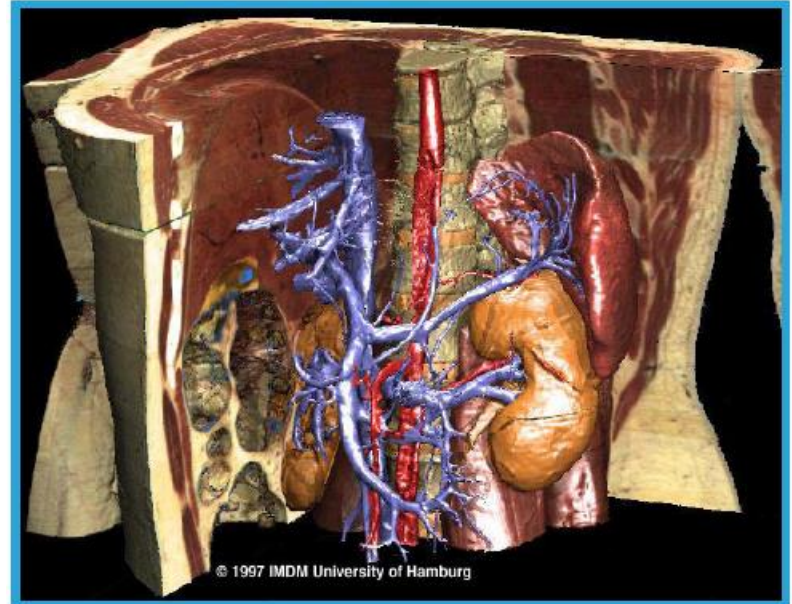
- Various input datasets and objects
- High interactivity for the user



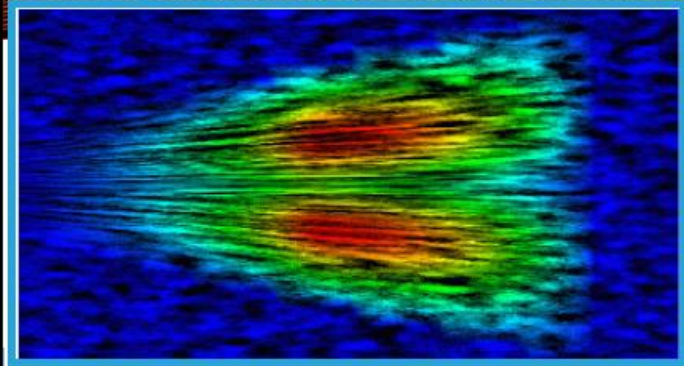
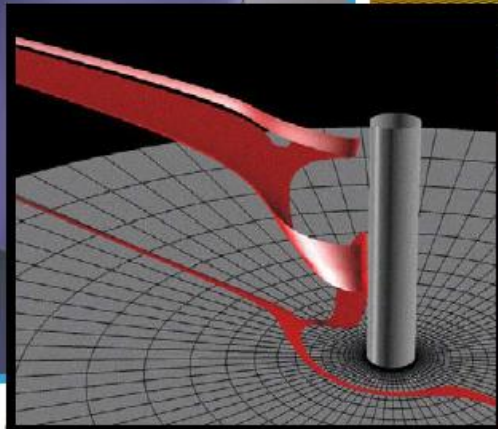
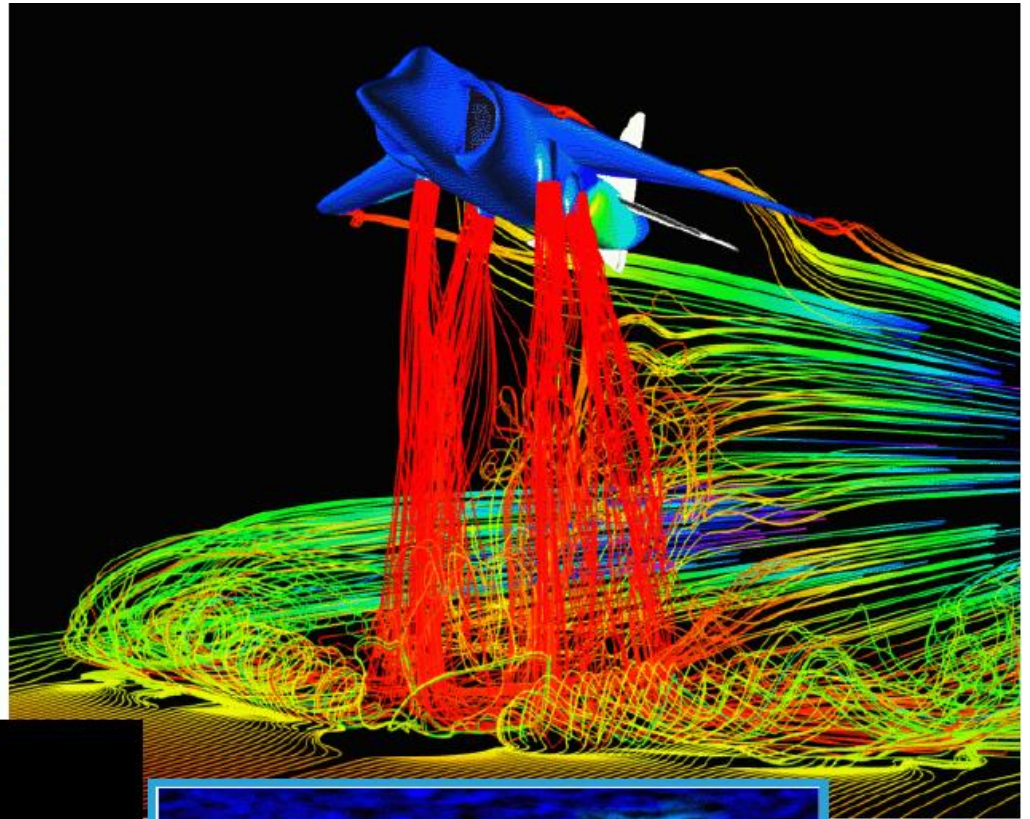
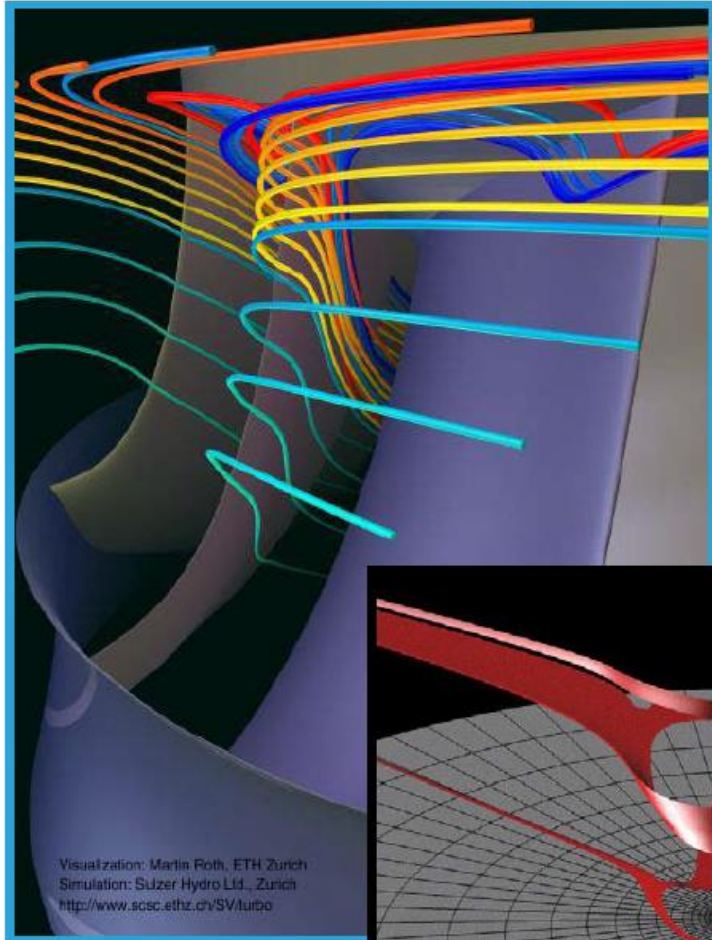
Visualization today

- Medical data (MedVis, VolVis)
- Flow data (FlowVis)
- Abstract data (InfoVis)
- GIS data
- Historical data (archeology)
- Microscopic data (molecular physics)
- Macroscopic data (astronomy)
- Big data
- ...

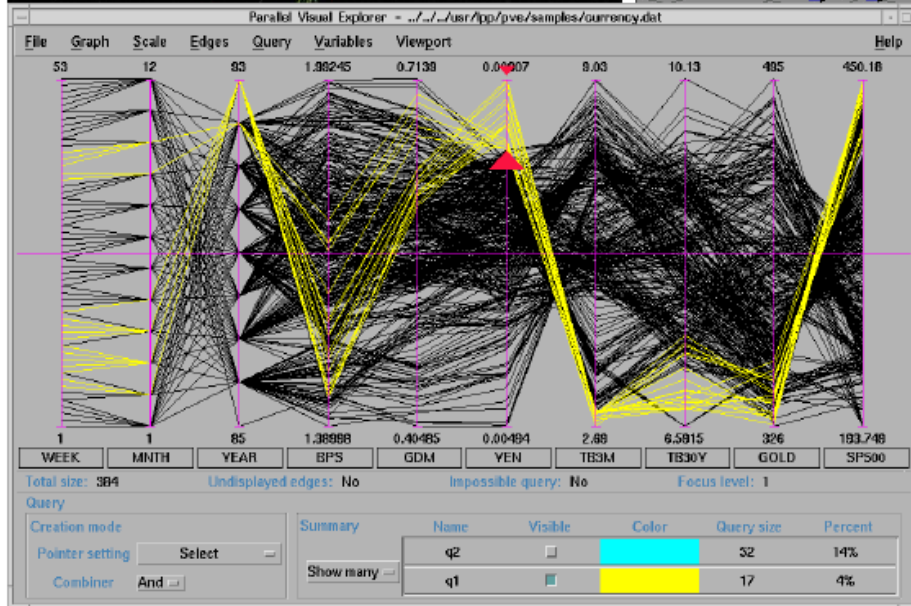
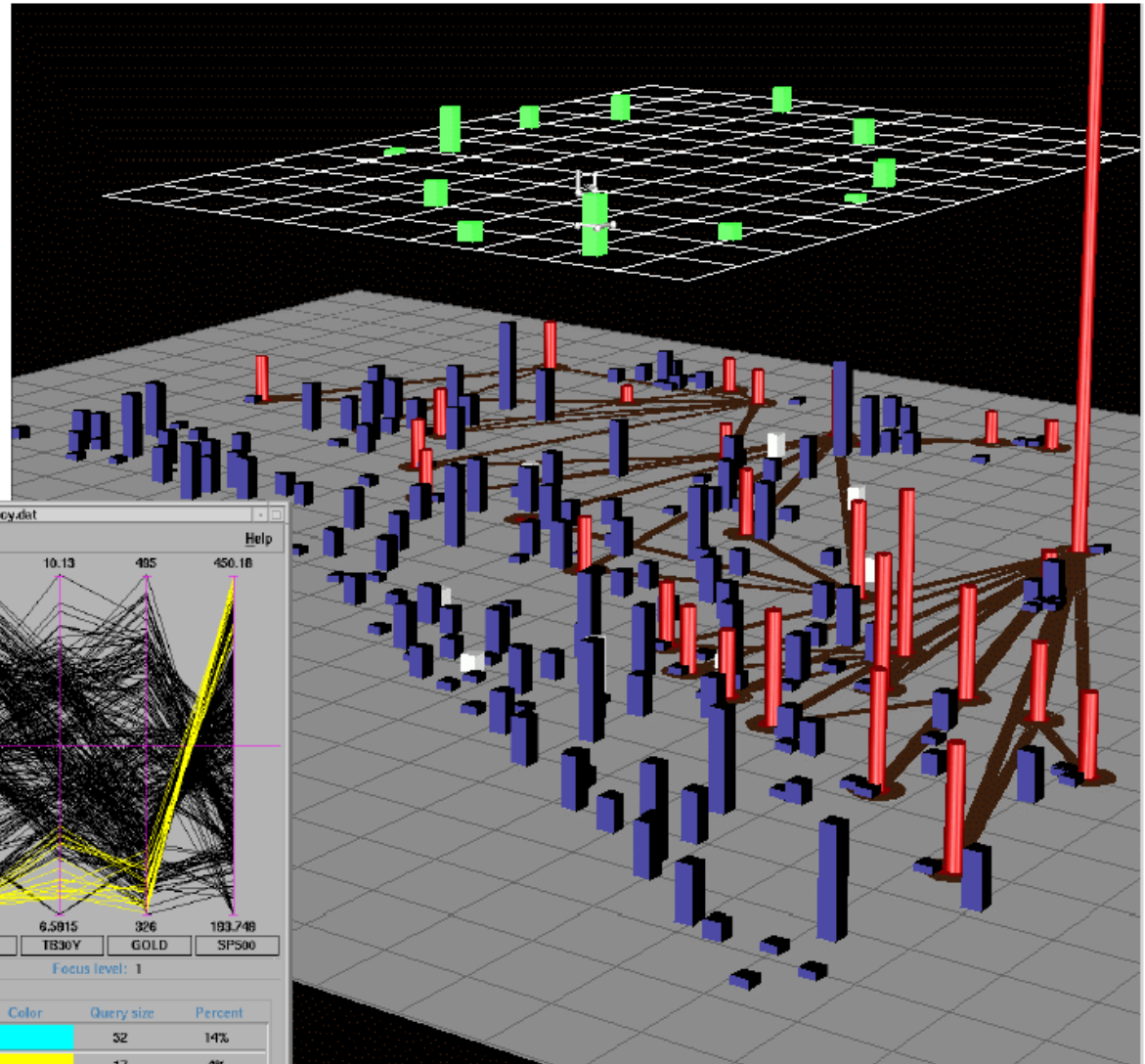
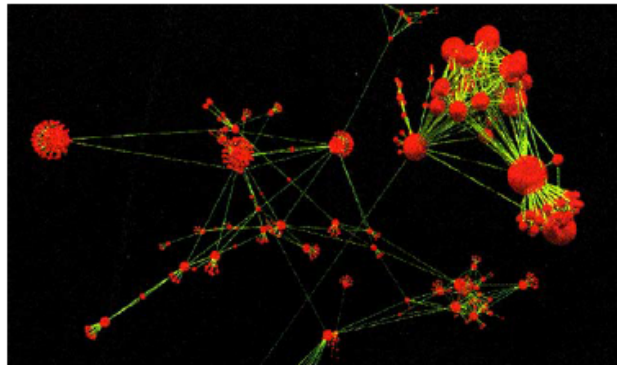
Medical visualization



Flow visualization



Abstracted visualization

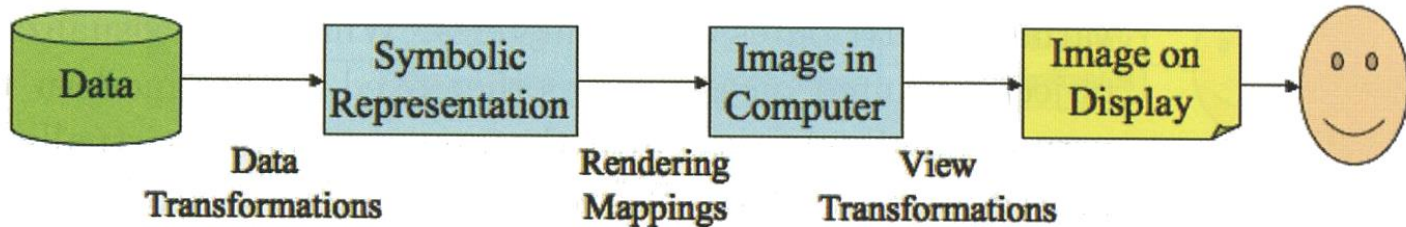


Visualization vs. computer graphics

- Is visualization a subset of CG or is CG a subset of visualization?
- CG – goal is the realism, art, entertainment
- Visualization – goal is an efficient conveying of the information

Pipeline

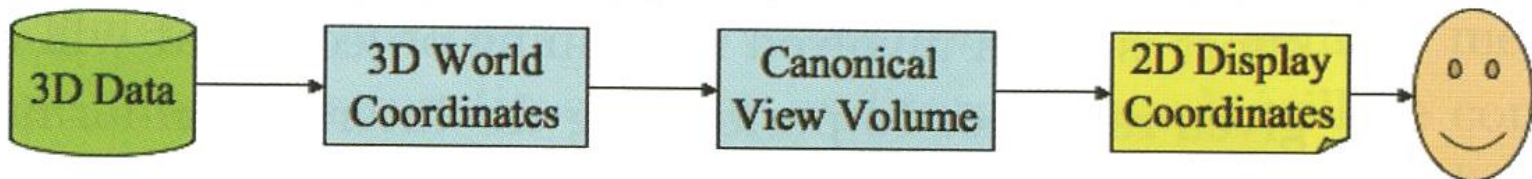
- Input data analysis
- Input requirements analysis
- Mapping data onto screen



- Enabling interactive manipulation

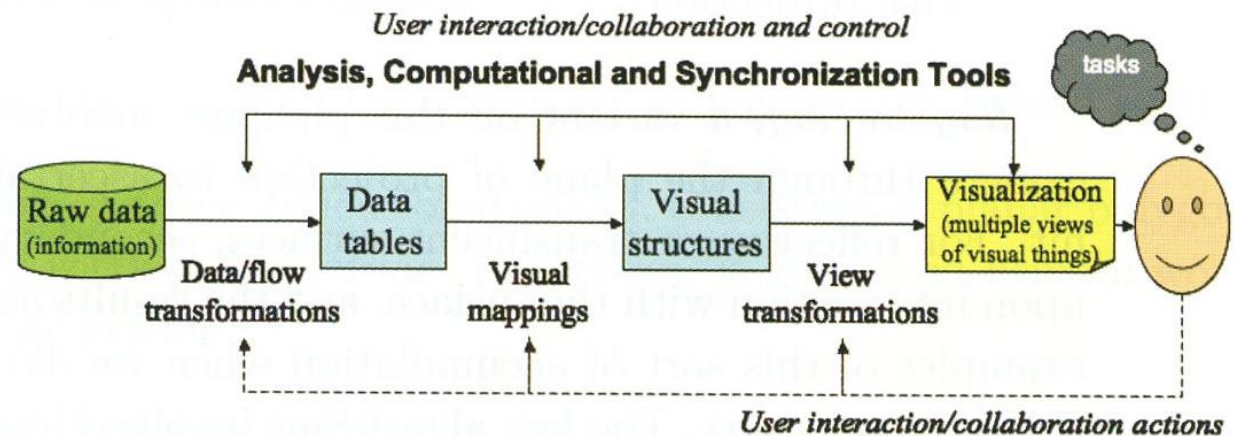
CG Pipeline

- Modeling
- Viewing
- Clipping
- Removing invisible parts
- Projection
- Rendering



Visualization pipeline

- Data acquisition
- Selection and processing of data
- Mapping of data
- Scene parameters settings
- Rendering



Data acquisition

- Measurement (CT/NMR)
- Simulation (flow simulation)
- Modeling
- ...

Data selection and processing

- Filtering – e.g., smoothing (noise removal)
- Resampling – e.g., to a lattice of different resolution)
- Deriving data – e.g., obtaining the gradient, curvature
- Data interpolation – e.g., linear, cubic
- ...

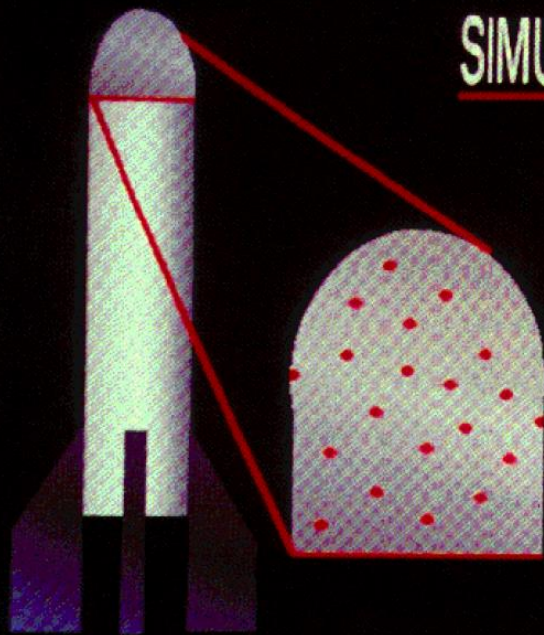
Data mapping

- Data are mapped to the representation suitable for rendering (e.g., geometry)
 - Computation of isosurfaces
 - Mapping to glyphs, icons
 - Computation of the distribution of data in a graph
 - Determining the attributes of voxel data (color, transparency, ...)
 - ...

Generating images

- Using computer graphics principles
 - Visibility computation
 - Lighting
 - Alpha blending
 - Animation
 - ...

SIMULATION DATA



Geometry: Surface Splines

Sampling Points:

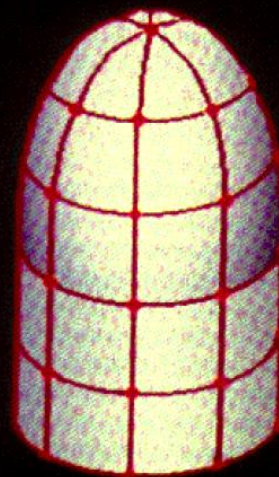
X, Y, Z

Temperature

Pressure

(irregular in space, time)

DERIVED DATA

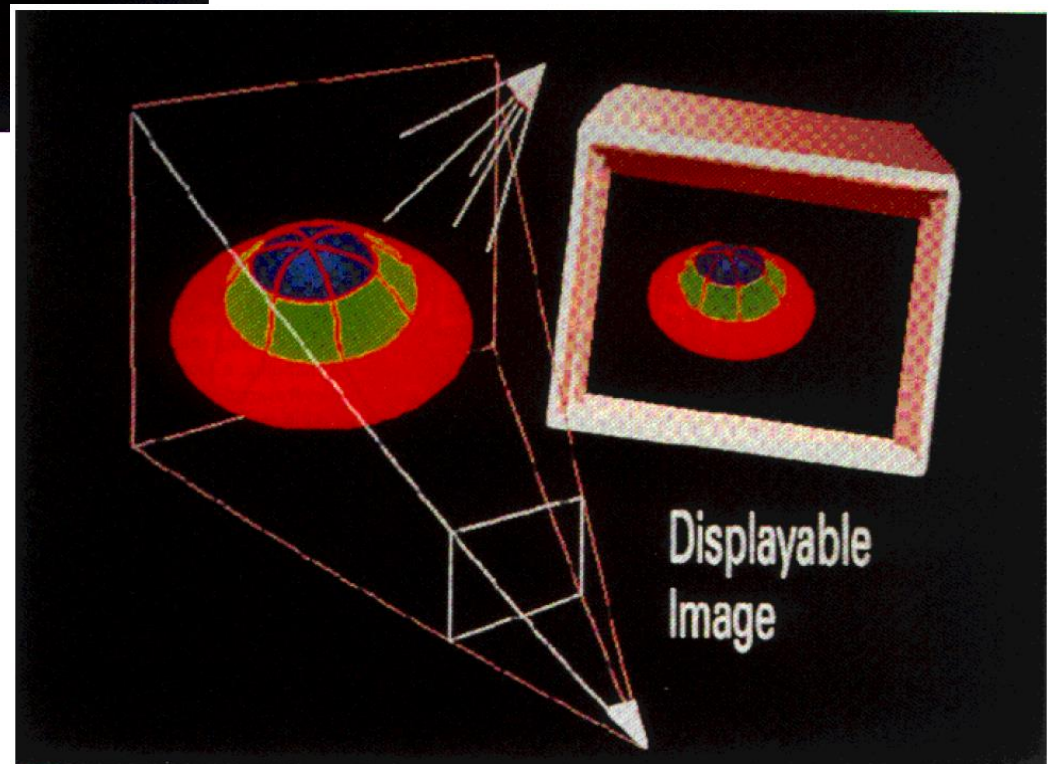
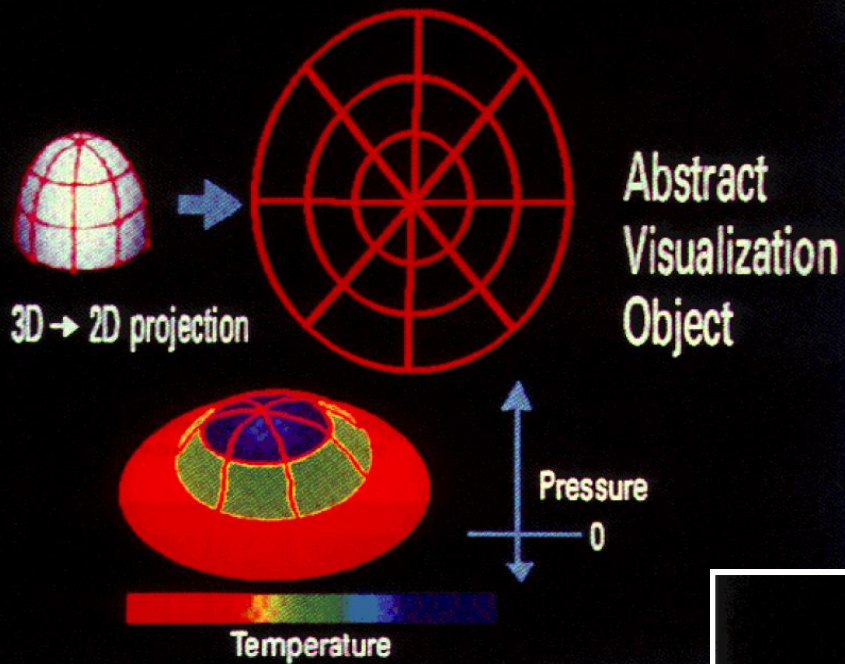


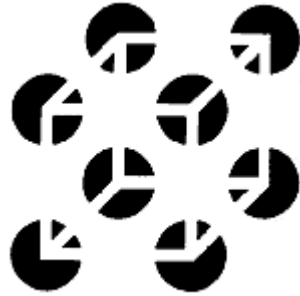
Geometry: Polygonal Patches
(Vertices at X, Y, Z)

Data at Vertices:

Temperature, Pressure

(Regular in Time)





cat.rulez.cz



www.yorksir.estranky.cz

Human cognition and processing of information



www.quertime.com



appsychtextbk.wikispaces.com

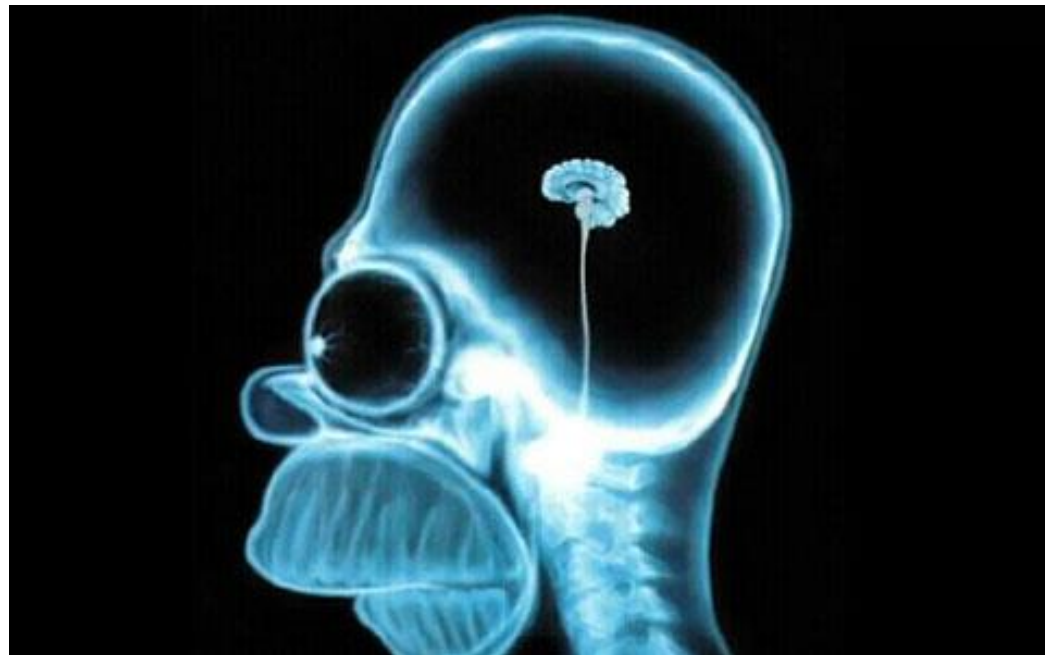
Human cognition

- Process of understanding, collecting, storing and interpreting the information (based on previous experience)
- Uses all human senses, sight and hearing are the most “important” ones

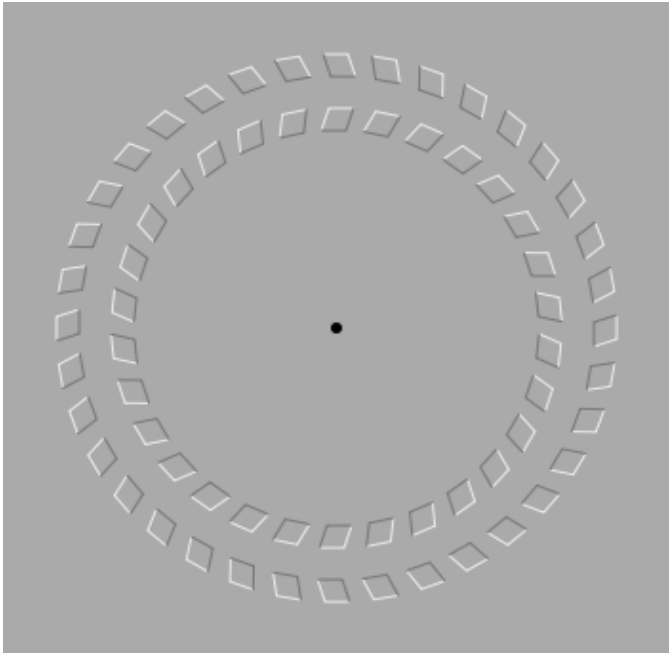


Human cognition

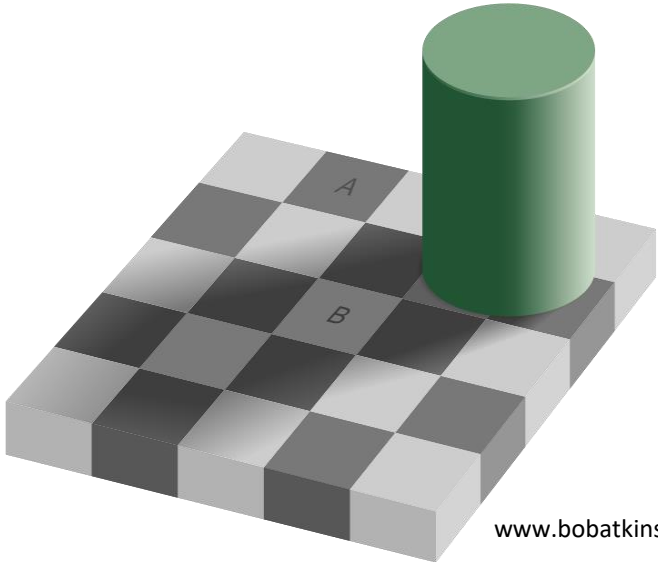
- Process of interpretation of the surroundings and forming its inner representation
- Desinterpretation – cognition error or targeted



Targeted desinterpretation – optical illusions



library.thinkquest.org



www.bobatkins.com

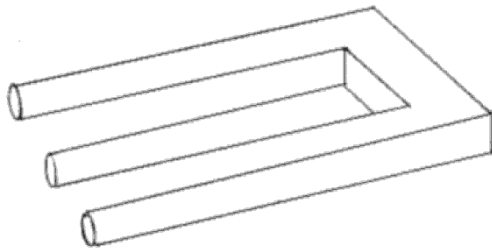


www.roumazeilles.net

Optical illusions



opticalillusionpictures.net



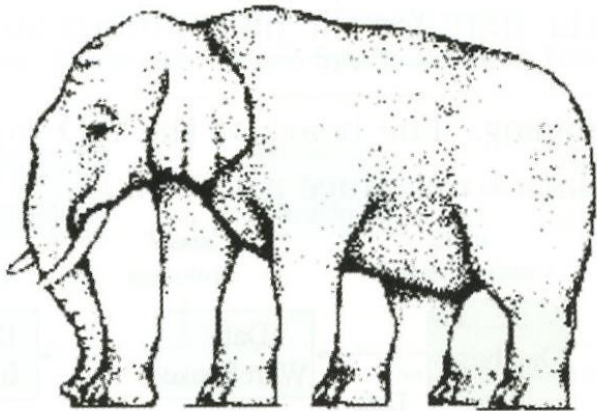
listverse.com



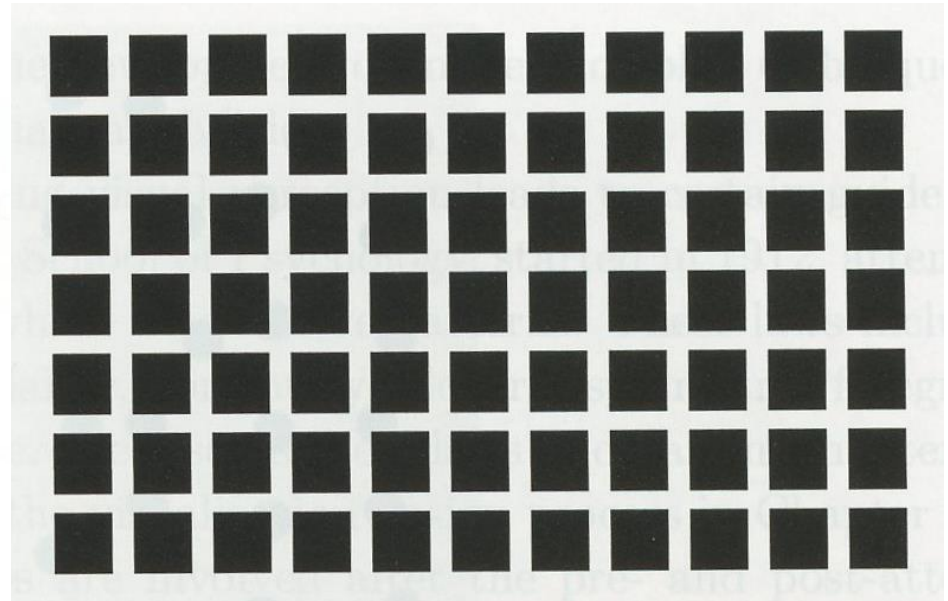
3d-pictures.feedio.net

Human cognition

- Sight is very limited



thinkoutsidetheboxtoday.com



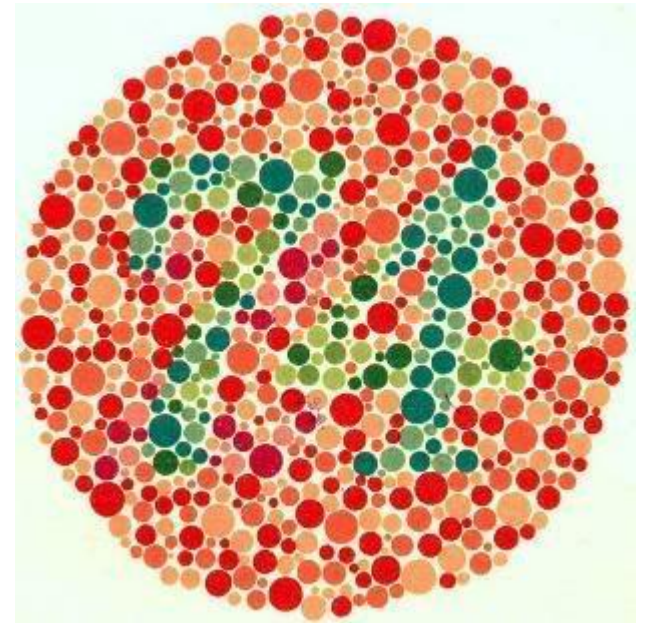
www.brainist.com

Human cognition

- Users are interacting with visualization according to their interpretation of visible information
- 8% of men problems with color perception



www.neitzvision.com



www.healthtap.com

Perception in the context of visualization

www.streetartutopia.com

- Color
- Texture
- Movement



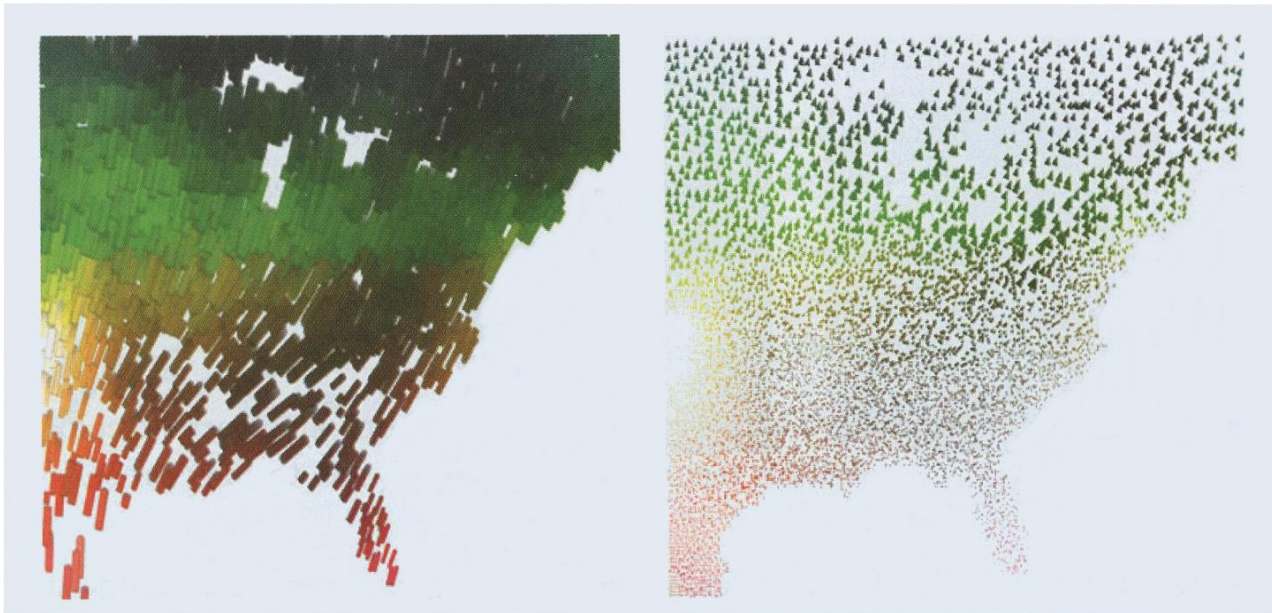
cz.123rf.com



blog.experimentsinmotion.com

Color

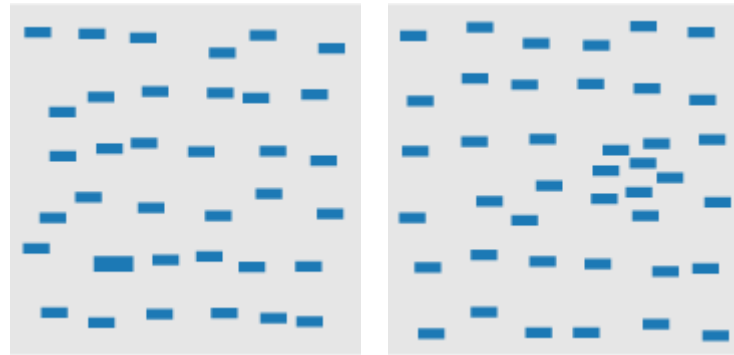
- Color balance – uniform distribution of color values in the whole range
- Distinguishability – in a given discrete palette each color has to be similarly distinguishable from the others
- Flexibility – colors can be selected from any place of the color space used



Healey a Enns – historical record of climate in eastern part of USA. Color = temperature, brightness = wind speed, orientation = rainfall, size = cloudiness, density = frequency of freeze

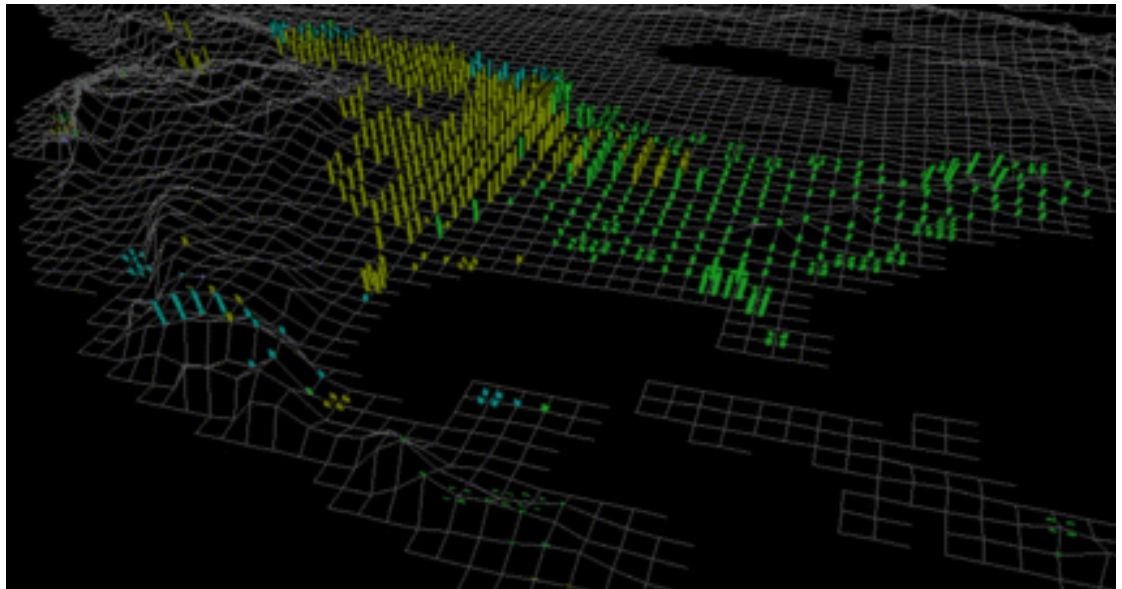
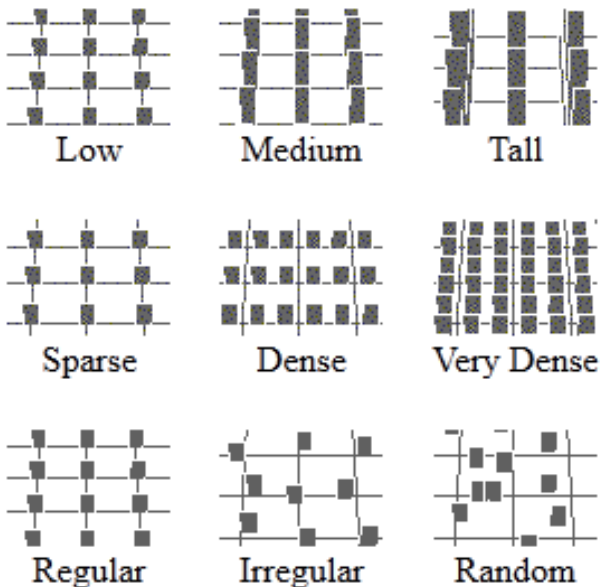
Texture

- Healey and Enns – pexels (perceptual texture elements)
- Size and density are well perceivable, variations in regularity are perceived worse



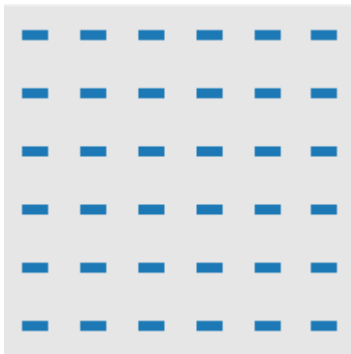
Texture

- Poxel can have 3 discrete values (height, density, randomness)
- Visualization of areas with large land cultivation (height = degree of cultivation, density = type of soil, randomness = crop type)



Movement

- Animation of particle systems, color changes, ...
- In general, changes in the image are attracting attention and improve the cognition process



flicker

<http://www.csc.ncsu.edu/faculty/healey/PP/>

Movement

- The position of the animated object in the scene is crucial
 - Such an object in the focus area is perceived differently than an object in the peripheral areas
- Additional movements in the scene are disturbing the perception process
 - The least disturbing is blinking, then oscillation movement, object transfers
 - The most disturbing is the movement of object in large distances
 - <http://openaccess.city.ac.uk/3752/1/Perceptually%20Uniform%20Motion%20Space.pdf>