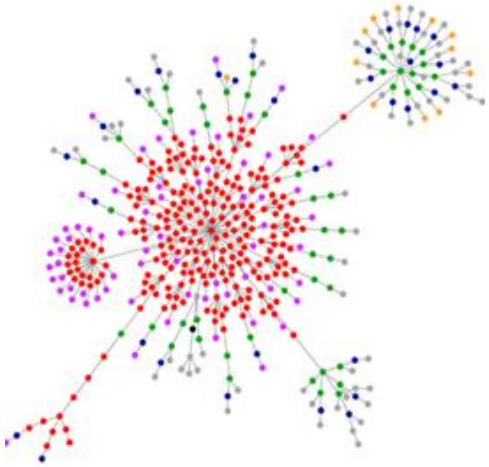
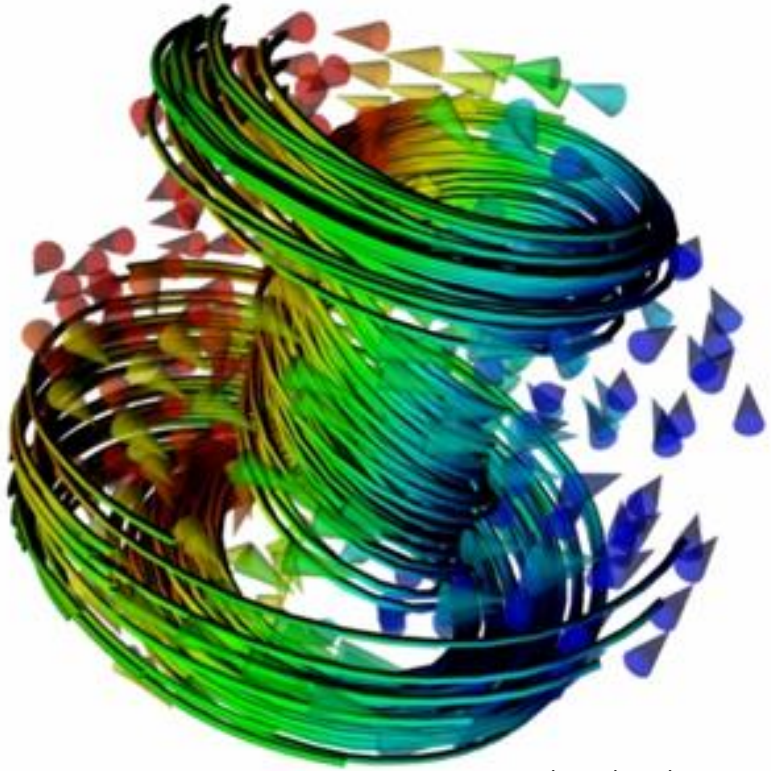


Selected topics in visual data science

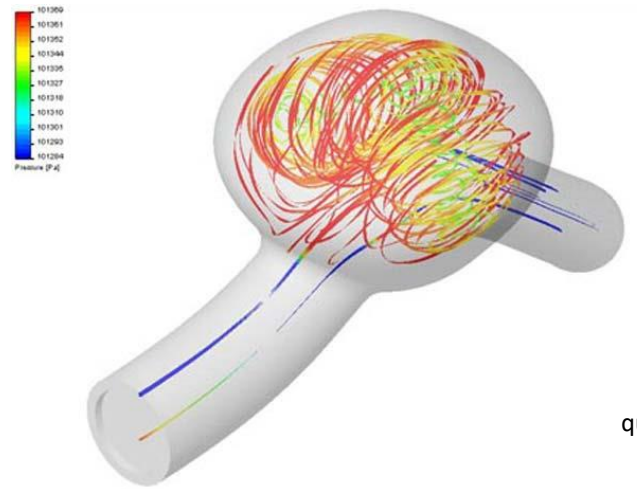
www.cehwiedel.com

Bara Kozlikova
Masaryk University
Brno, Czech Republic

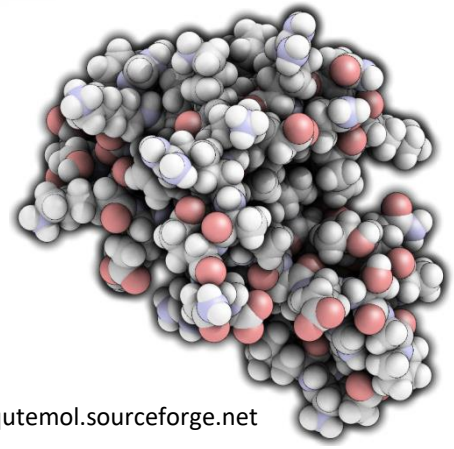
Universidad Nacional del Sur, Bahia Blanca
July 1 – 12, 2019



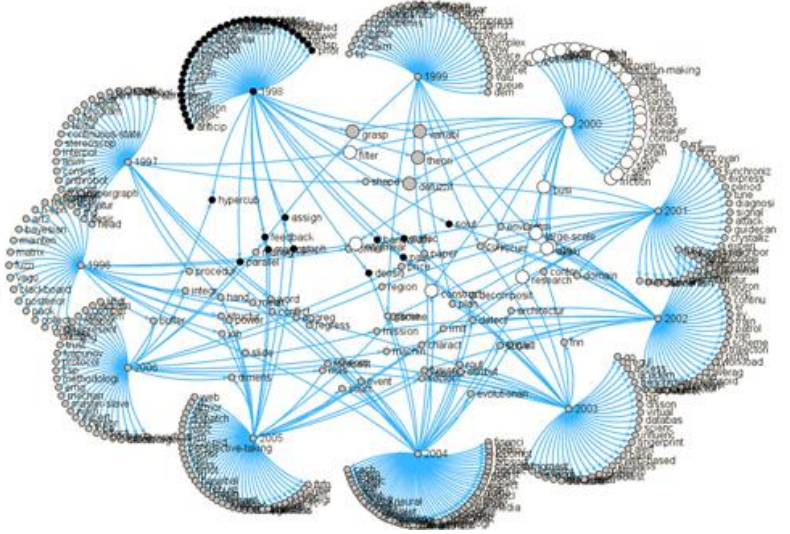
code.enthought.com



www.flometrics.com

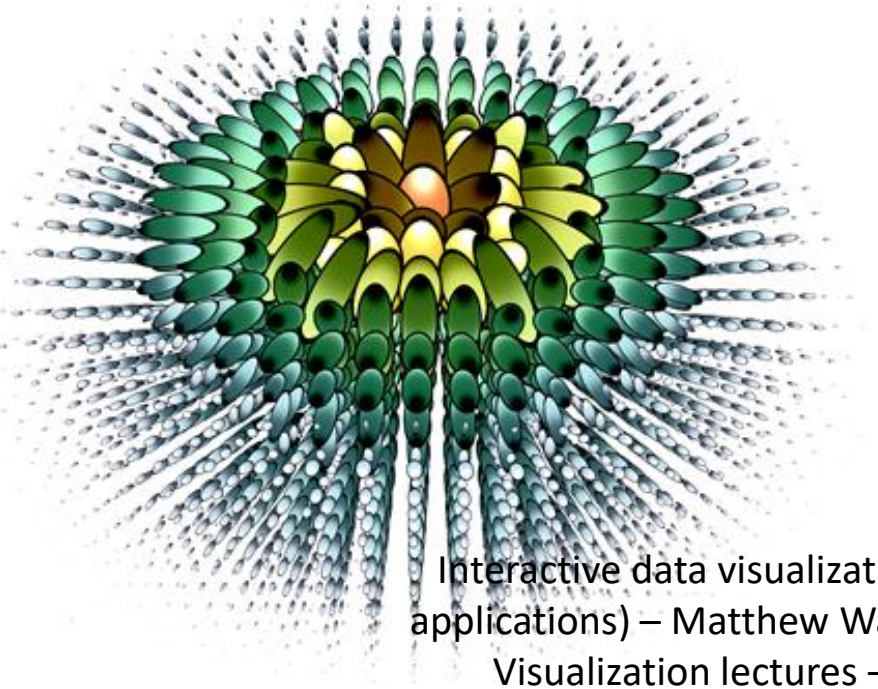


qutemol.sourceforge.net

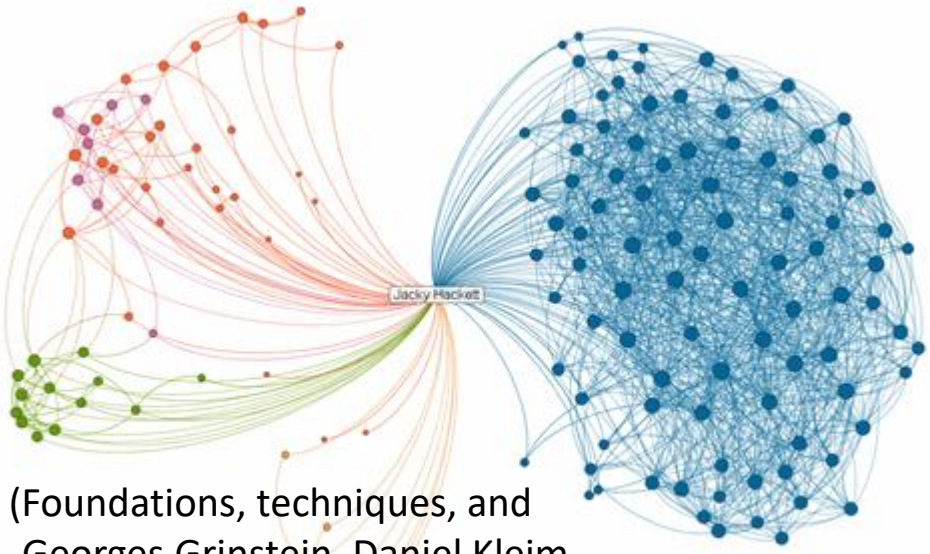


informationandvisualization.de

1. Introduction to Visualization



visservices.sdsc.edu



www.jackyhackett.com

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

Visualization lectures – Eduard Gröller, Helwig Hauser

Visualization Analysis and Design – Tamara Munzner

What is visualization?

- Conveying the information using a graphical representation

eagereyes.org

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**

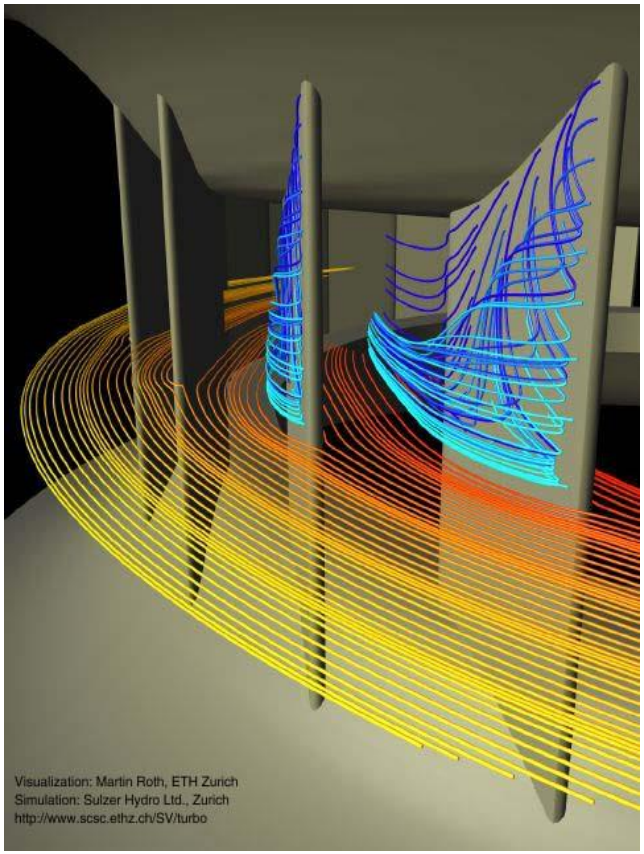
- Computer Graphics, but not photorealistic rendering

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…

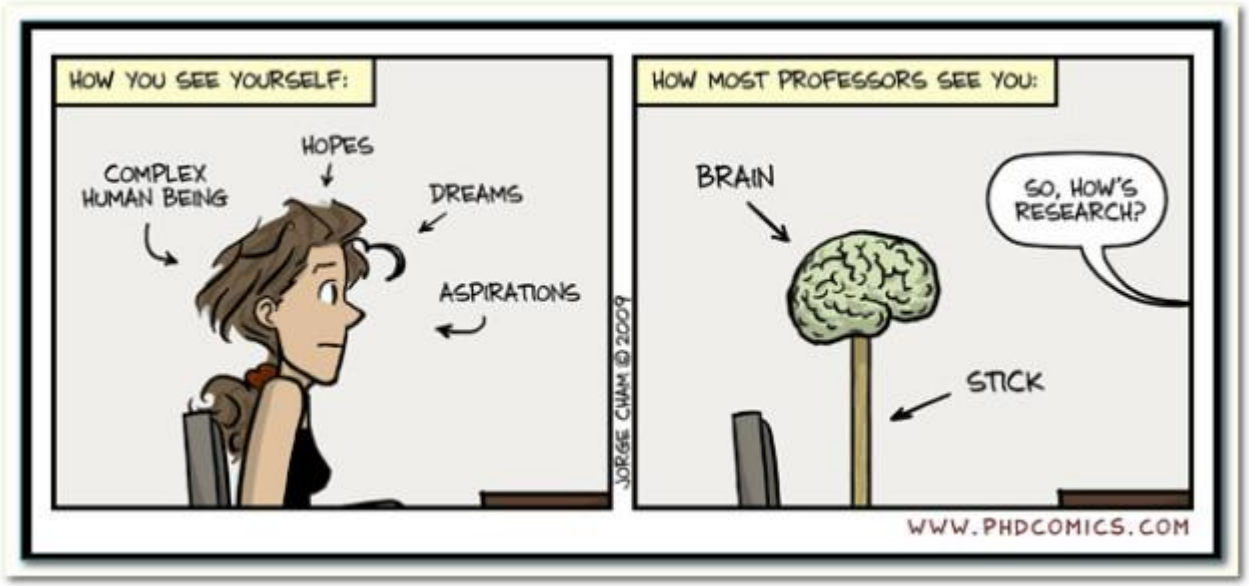
Today's lecture

- Importance of visualization
- History
- Vizualization today
- Relation between visualization and other fields
- Visualization pipeline
- Human perception



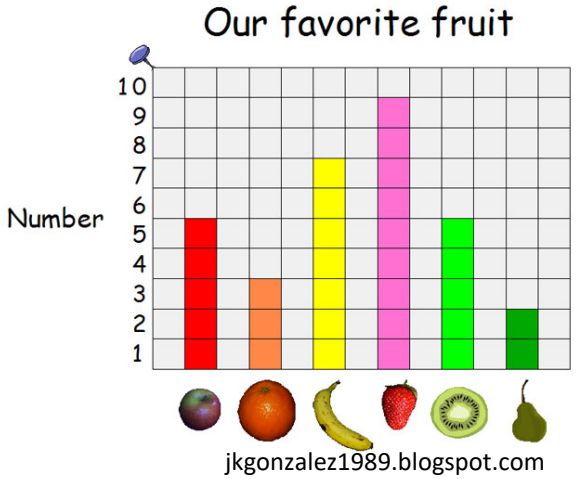
Why creating visualizations?

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



Three main functions of visualization

- **Data storage**
  - Photos, blueprints, …
- **Analysis of information**
  - Data processing, evaluation, interaction



- **Conveying the information**
  - Data sharing, cooperation, highlighting important aspects of data

Why is visualization so important?

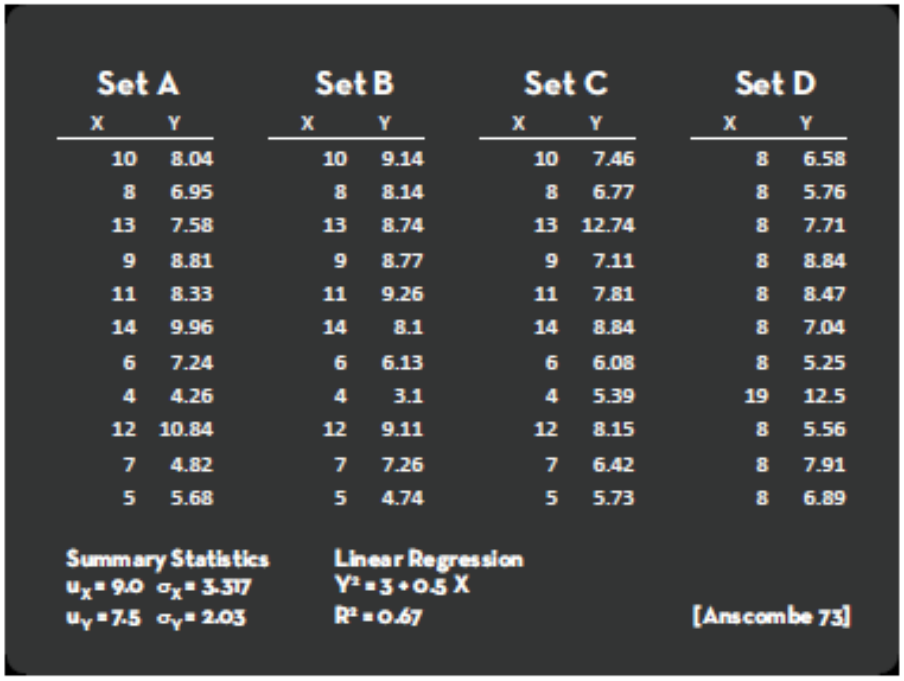
- **Sight** is one of the main senses
- We are surrounded by visualization (newspapers, maps, weather forecast, stock market, statistics, posters, advertisement, …)
- Improving the decision process,

  better understanding

  of context of the data

under30ceo.com

Why is visualization so important?



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

What is the best way to present this data?

The Value of Visualization, Jeffrey Heer, Stanford University

Why is visualization so important?

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
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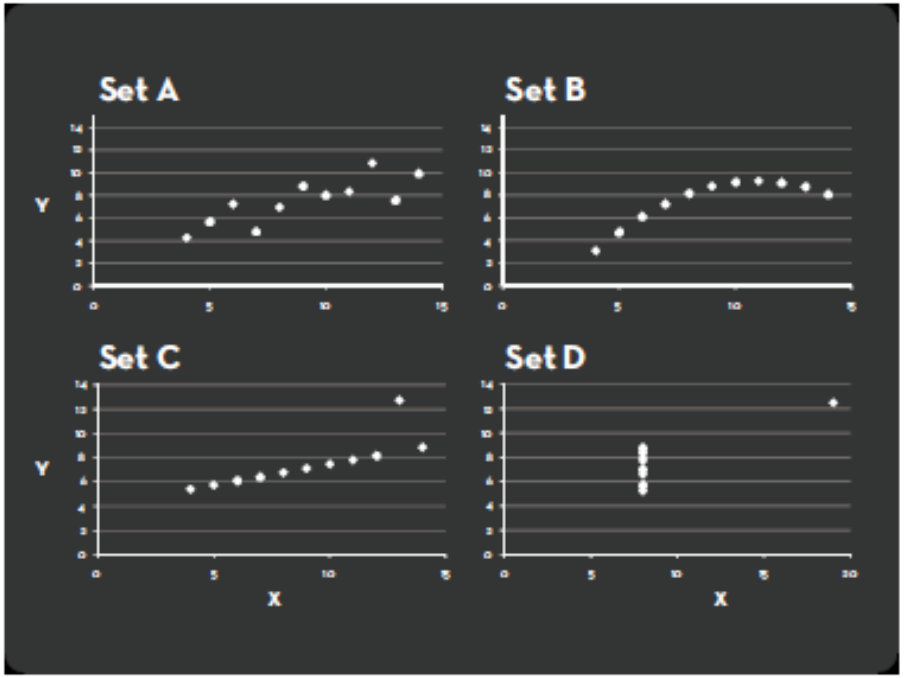
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

Summary Statistics
$u_X = 9.0$ $\sigma_X = 3.317$
$u_Y = 7.5$ $\sigma_Y = 2.03$

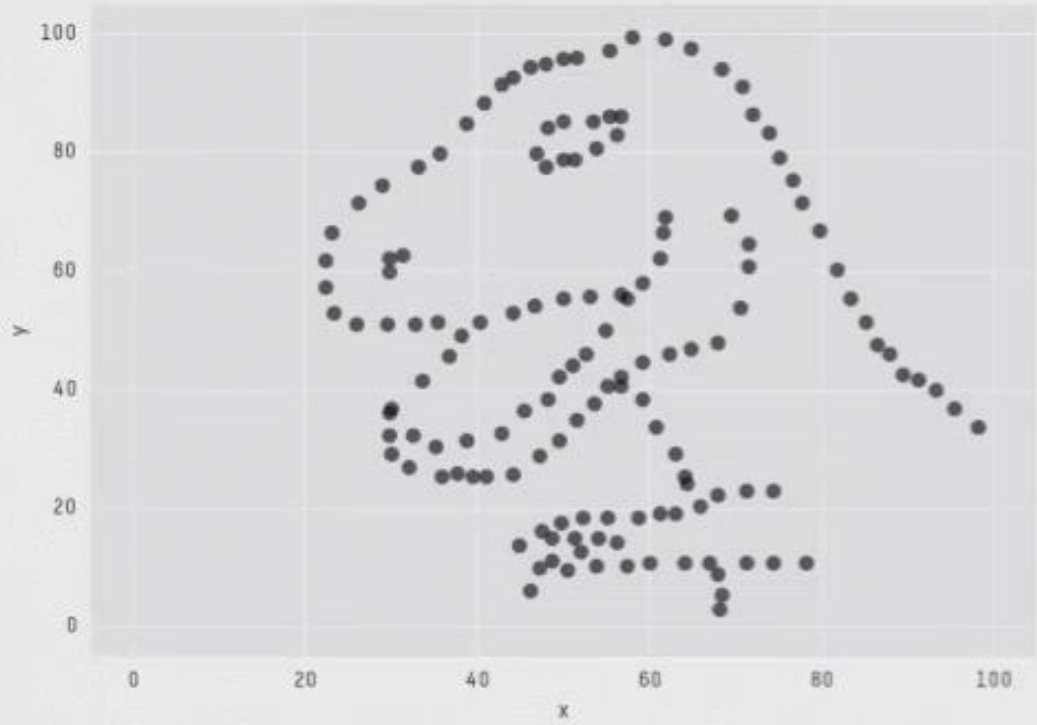
Linear Regression
$Y^2 = 3 + 0.5\ X$
$R^2 = 0.67$

[Anscombe 73]



The Value of Visualization, Jeffrey Heer, Stanford University

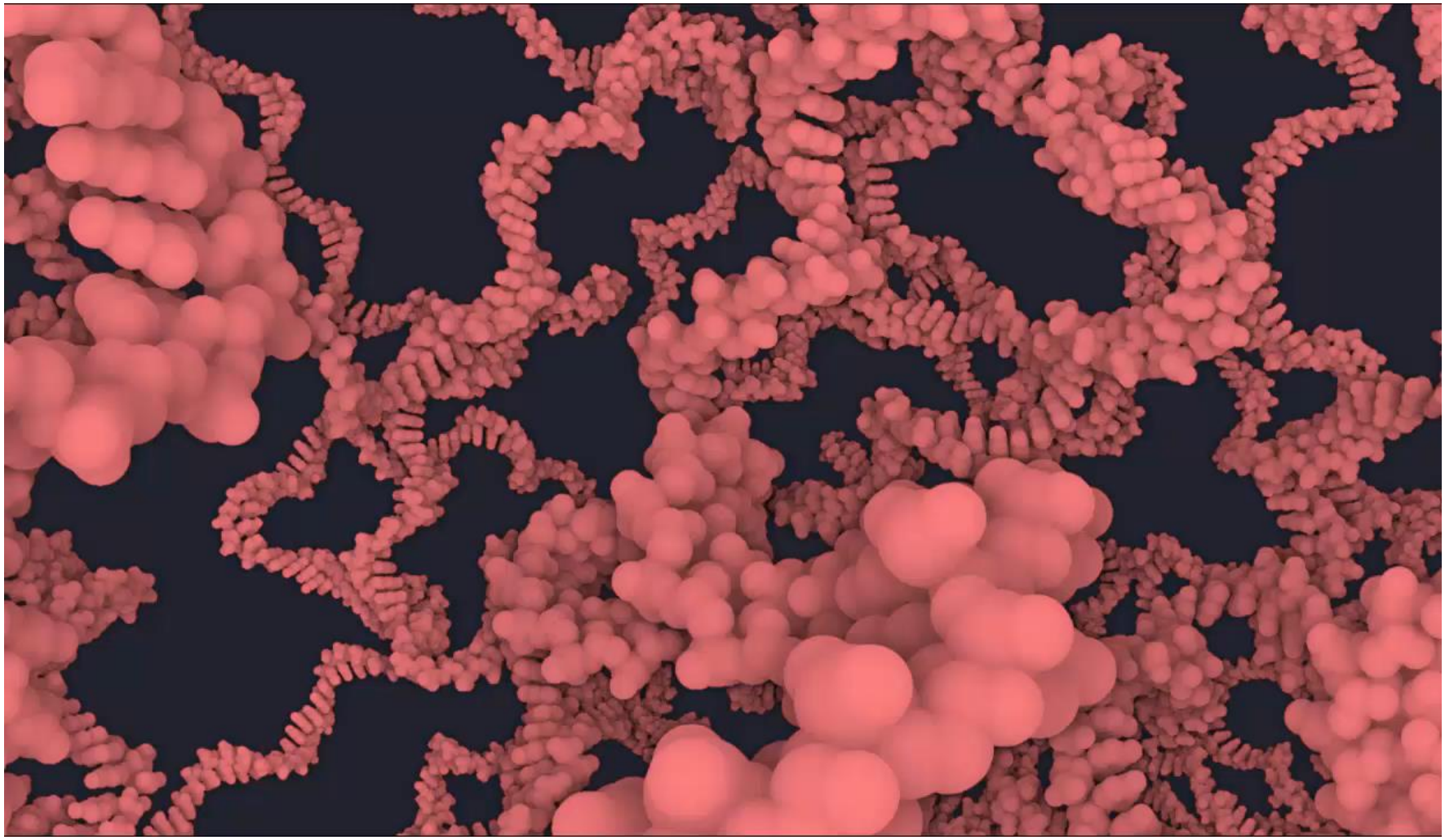
Why is visualization so important?



X Mean: 54.2659224
Y Mean: 47.8313999
X SD : 16.7649829
Y SD : 26.9342120
Corr. : -0.0642526

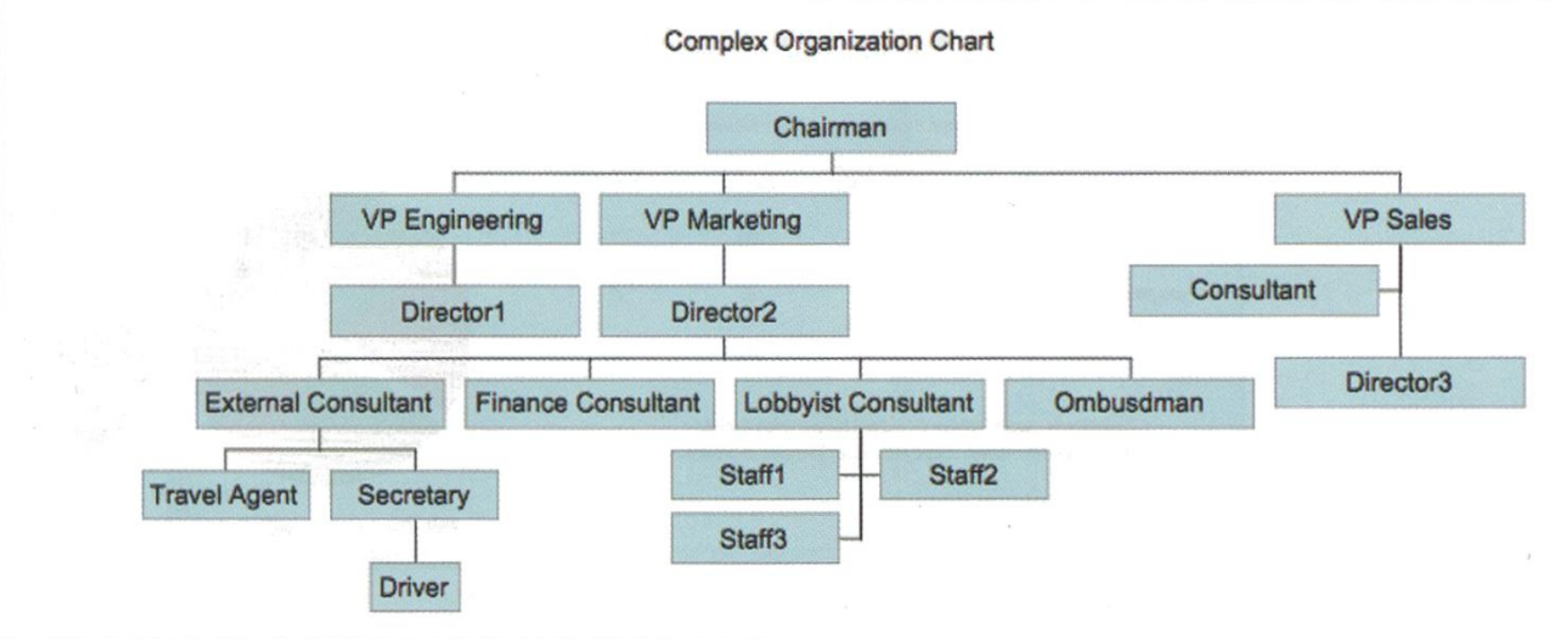
Matejka and Fitzmaurice: Same Stats, Different Graphs, CHI'2017

Why is visualization so important?



Why is visualization so important?

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



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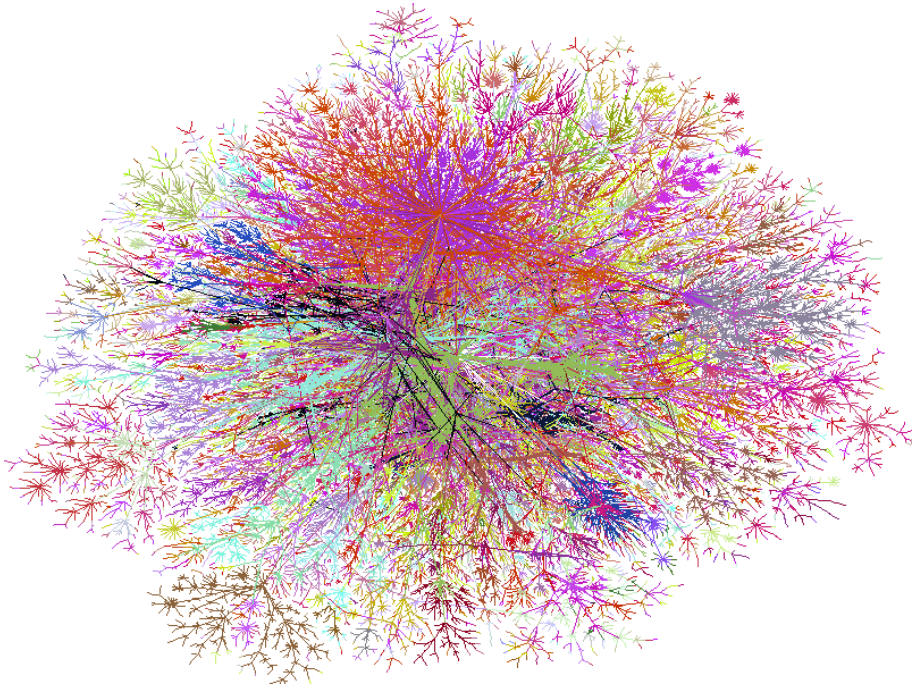
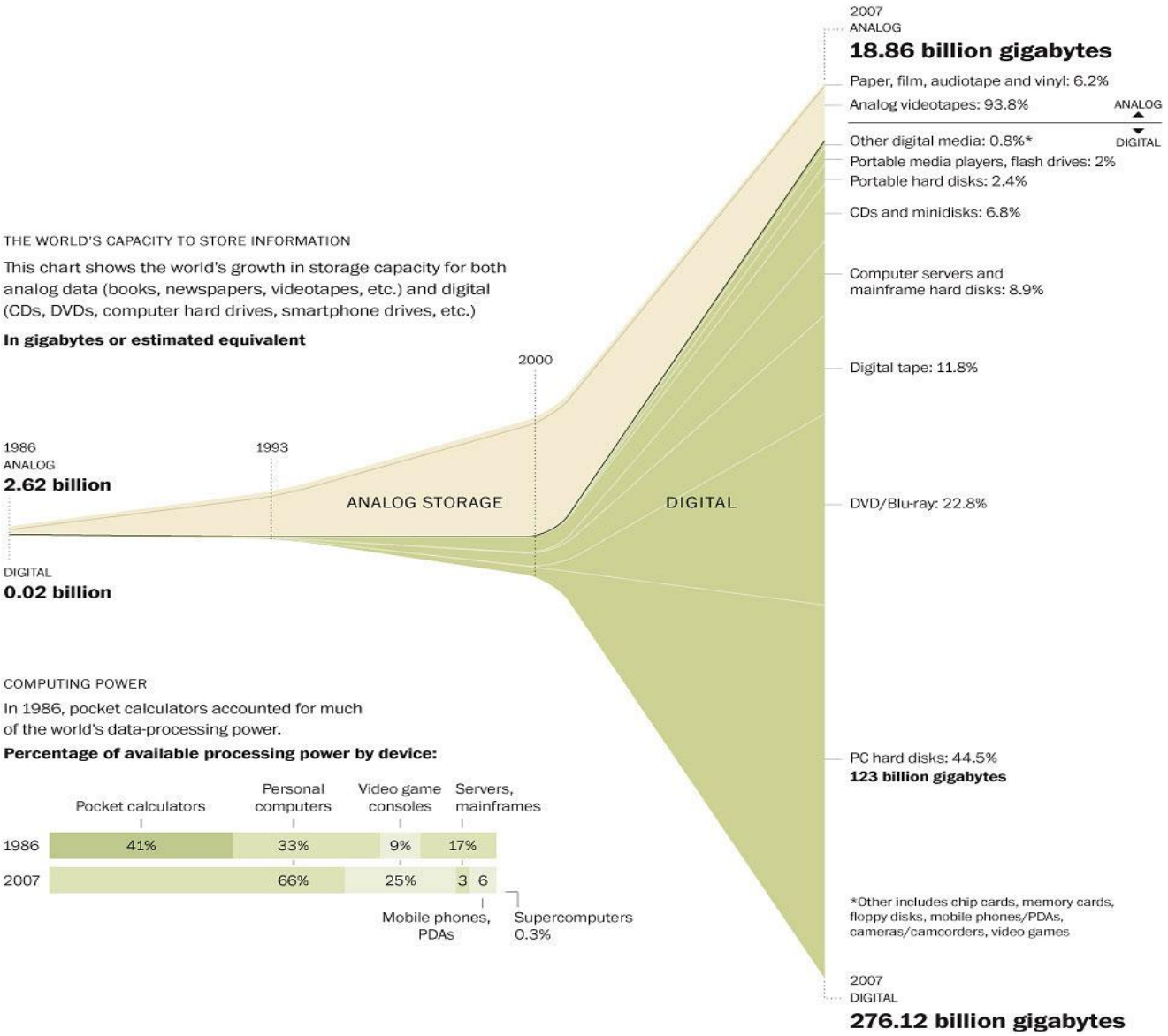
Why is visualization so important?

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



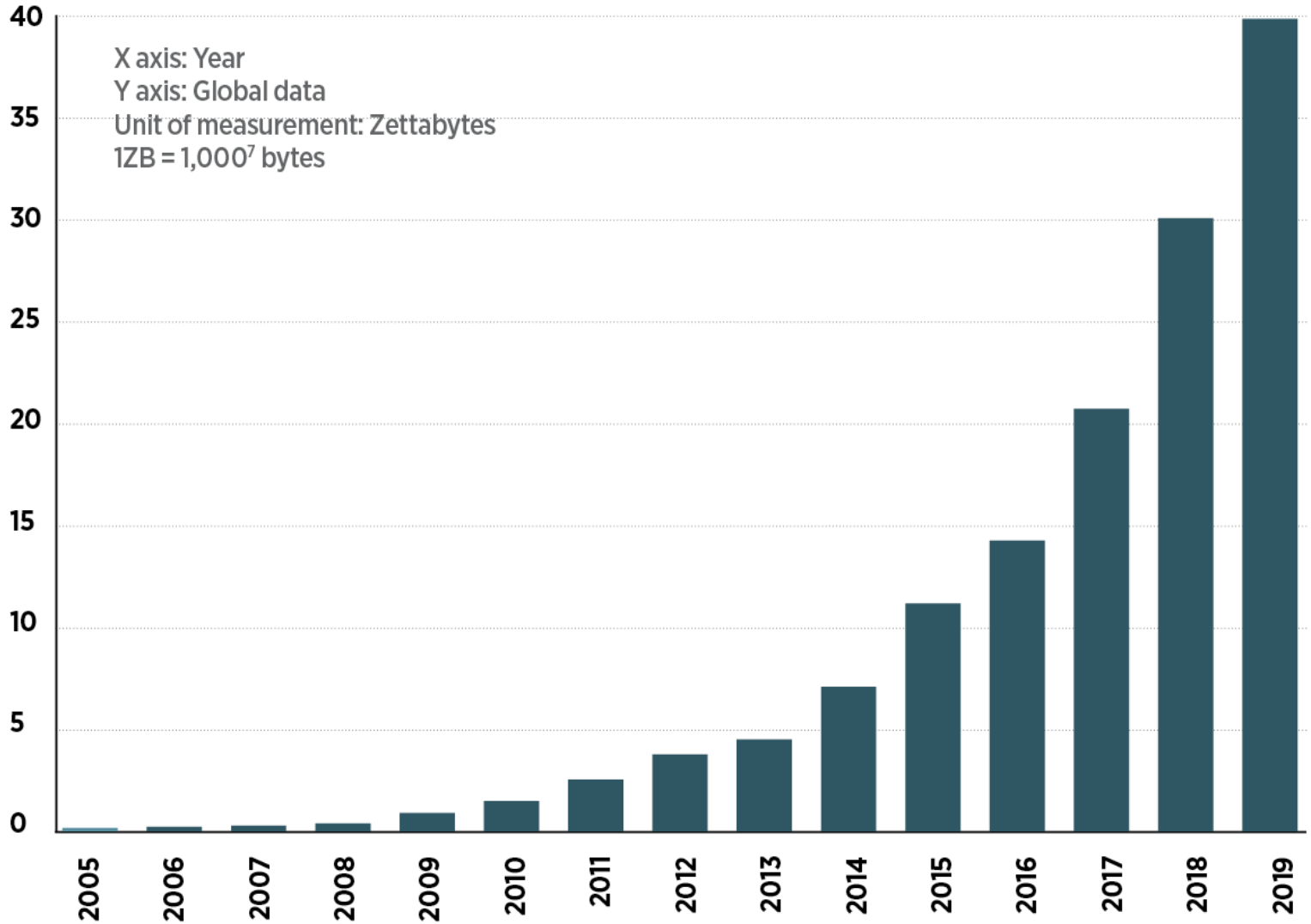
visualinsights.wordpress.com

“Current” size of data



techliberation.com

DATA GROWTH

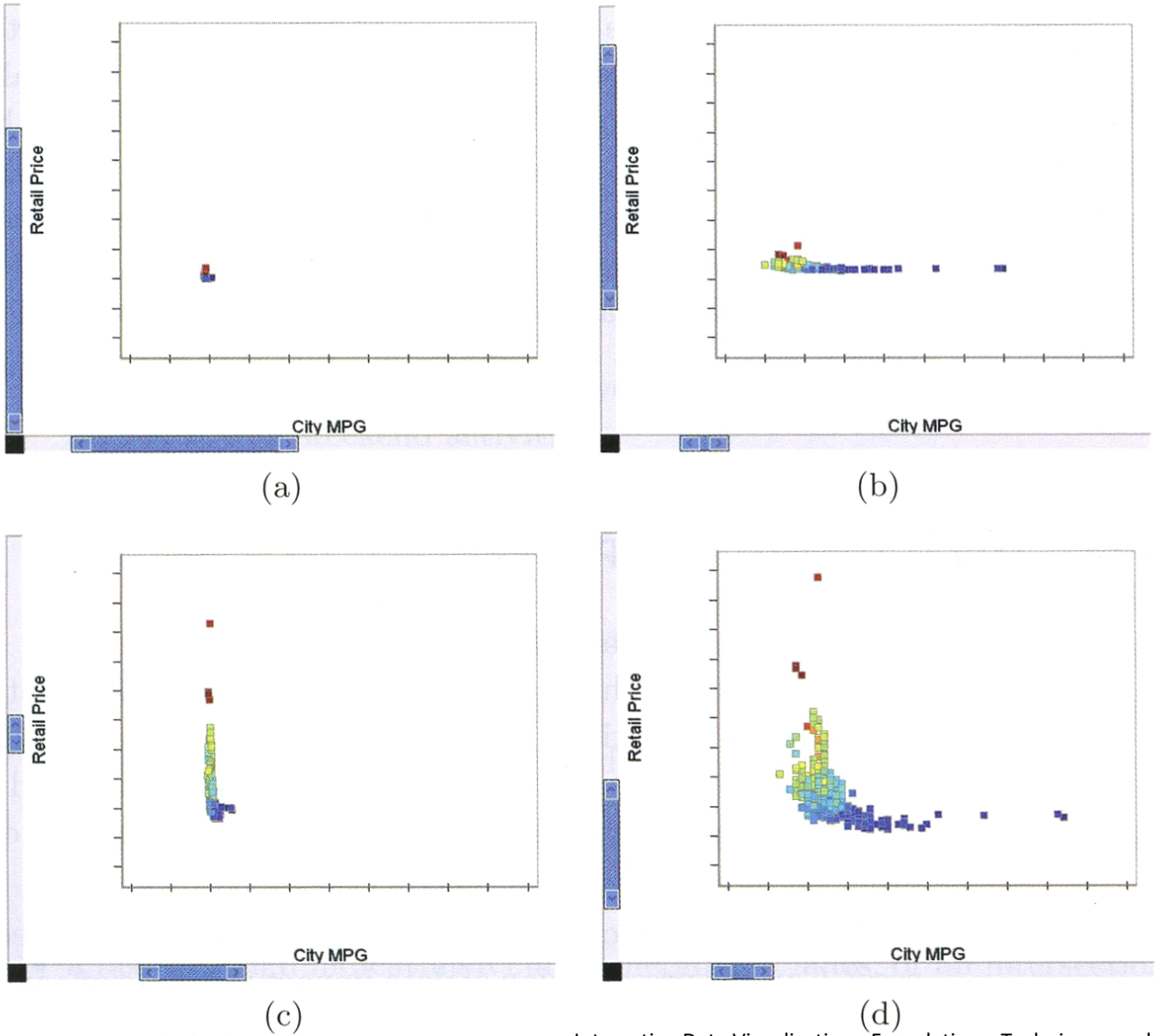


Note: Post-2013 figures are predicted. Source: UNECE

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



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This is where we started to draw taller bars to please you guys.

History

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

History

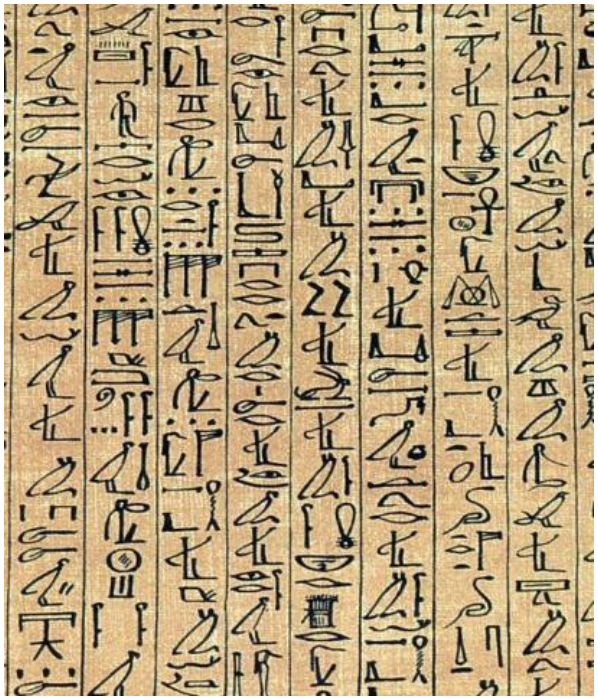
- Image-based communication appeared much earlier than written one

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.)

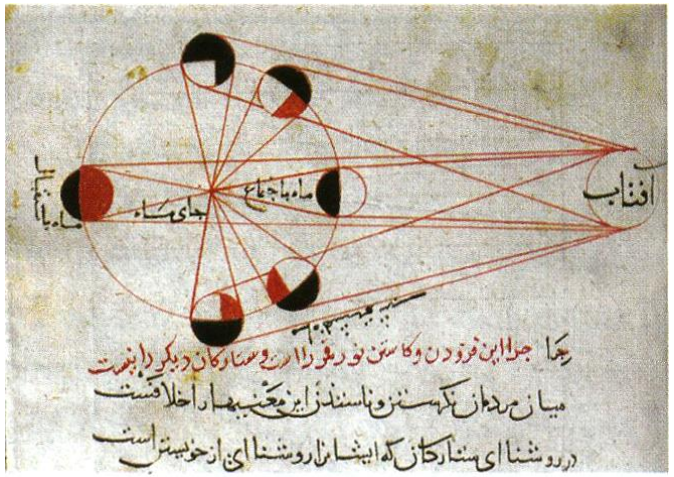
History

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

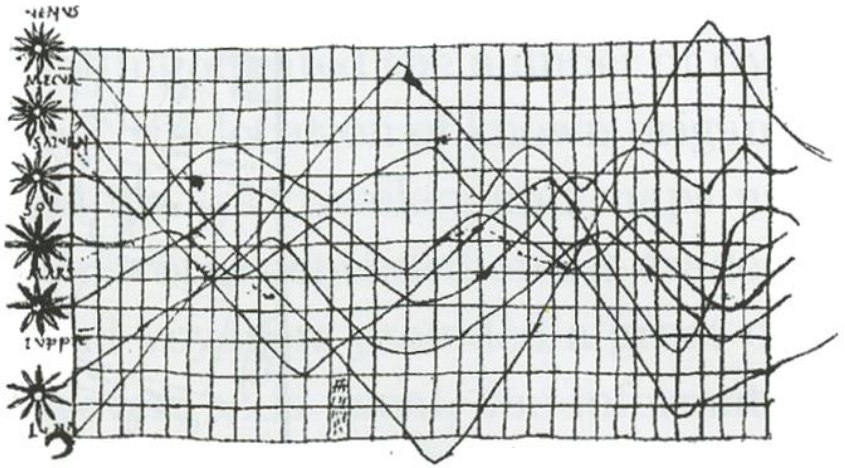
Peutinger map of Roman empire

History

- Moon phases (1030)

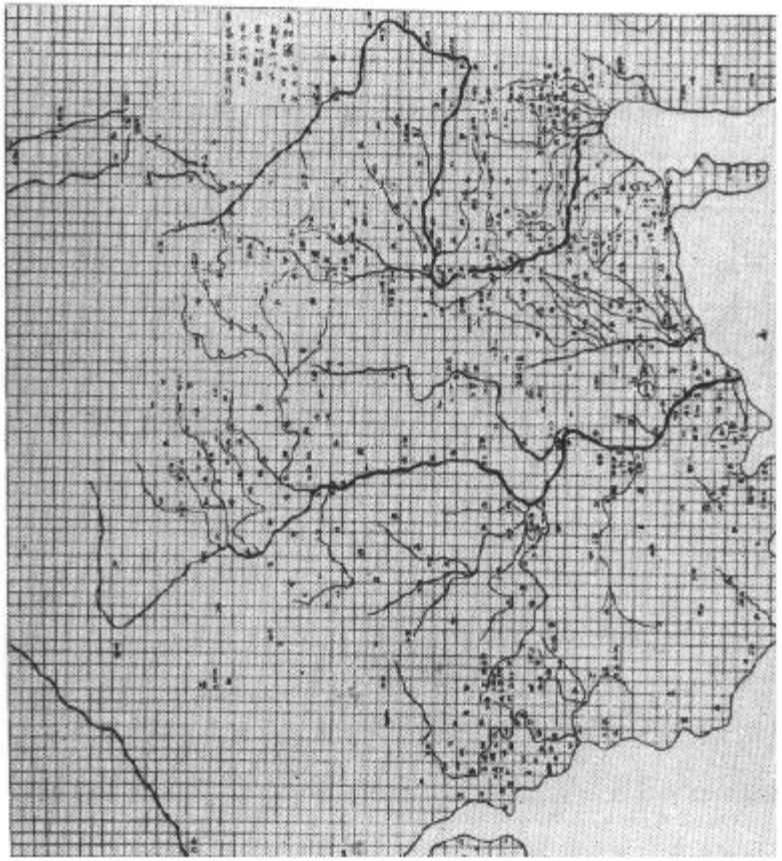


- Movement of planets

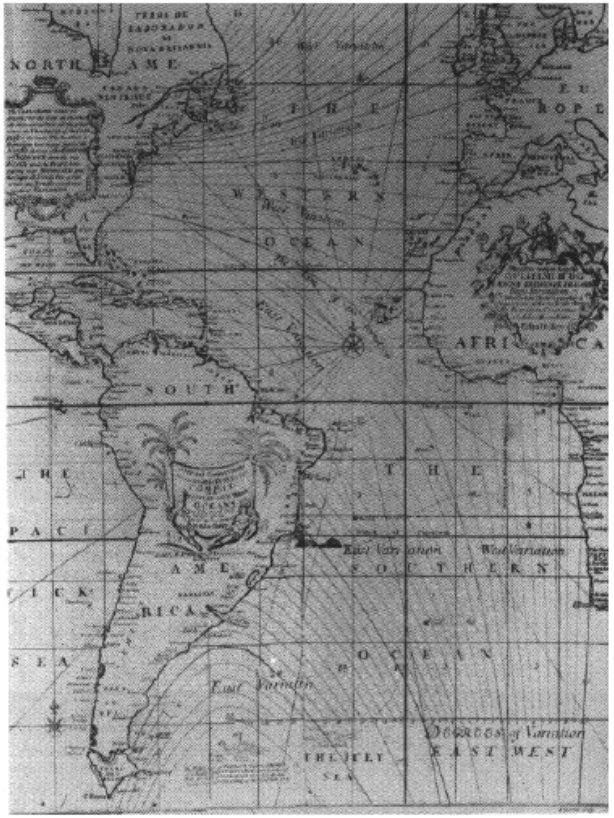


History

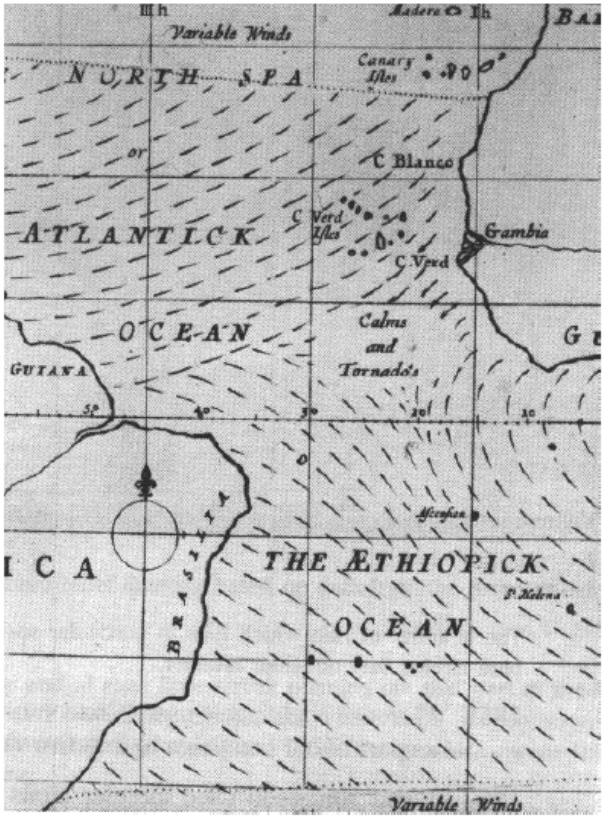
- China, 1137
- First geographic map using Cartesian coordinates
- Lattice with lines representing latitude and longitude



History – cartography



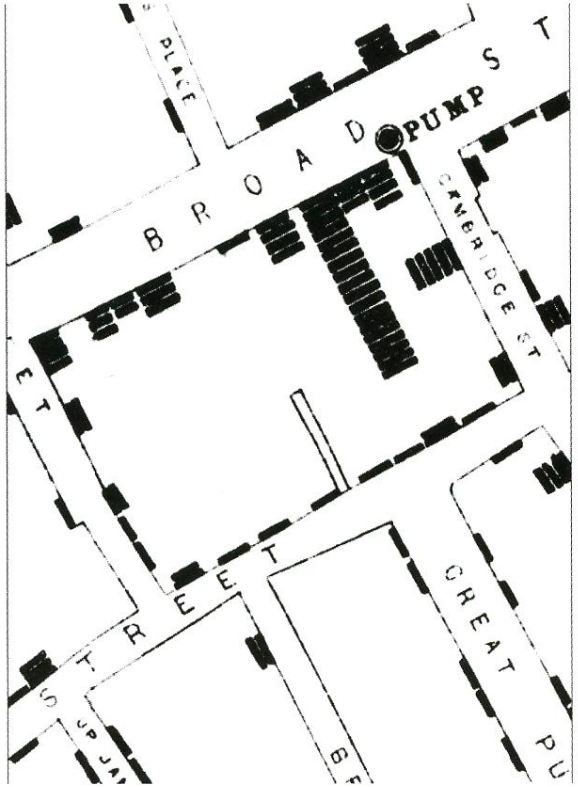
Isolines showing the deviations of compass



Visualization of winds

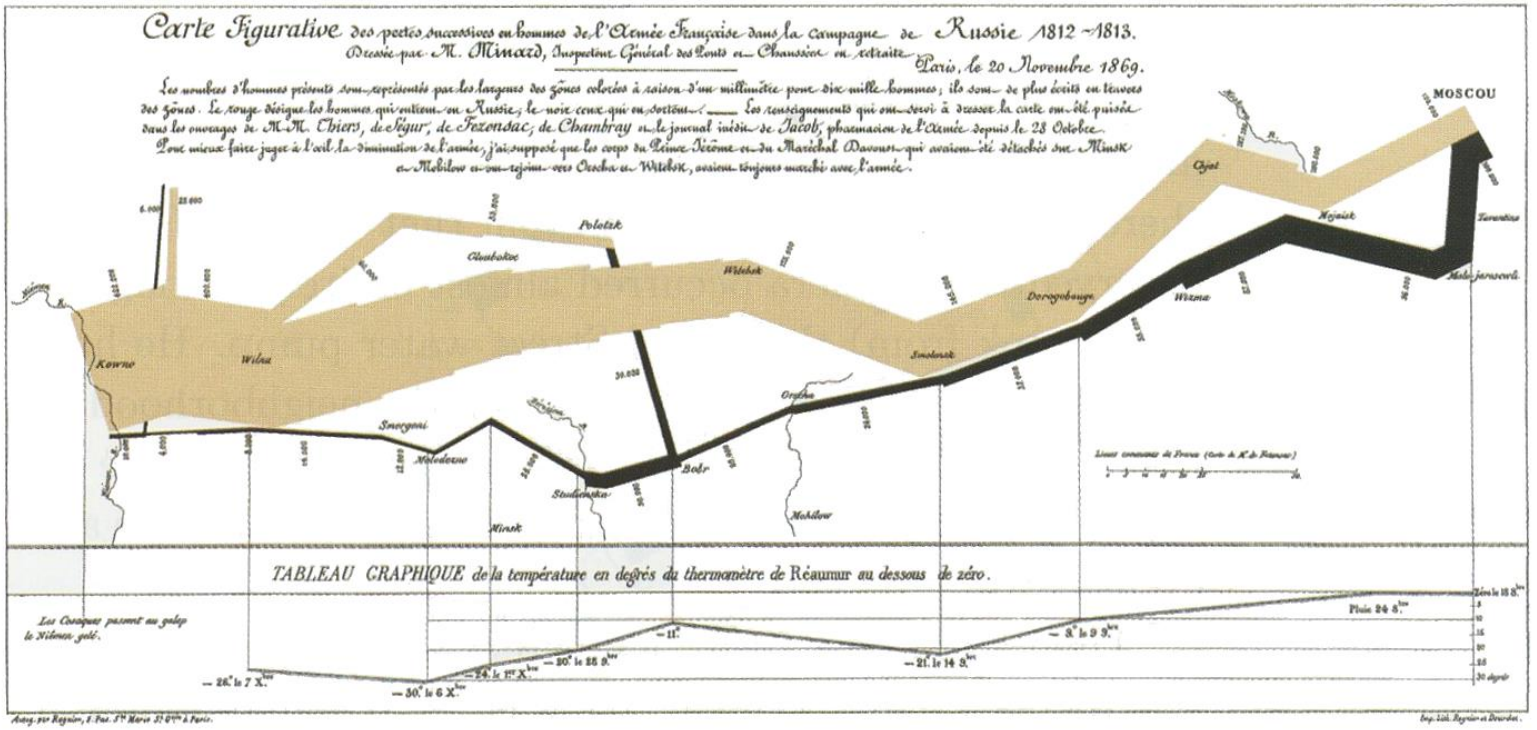
History

- In 1663 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



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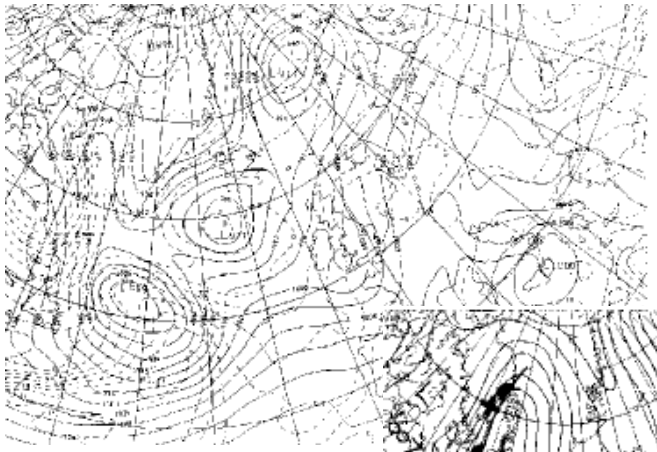
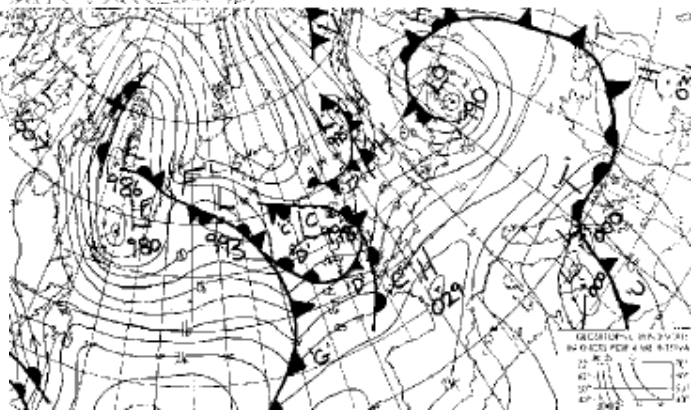
Meteorology

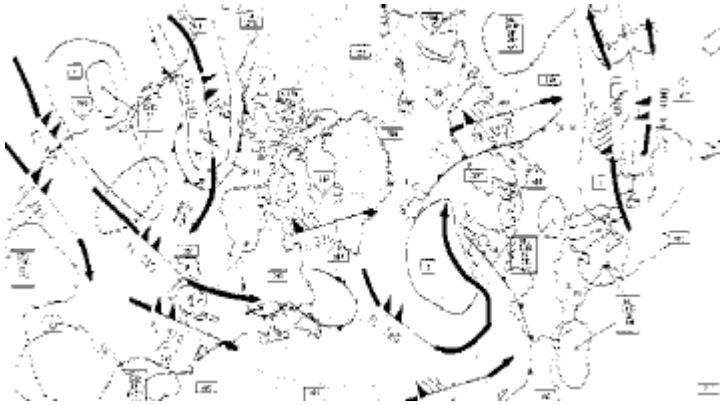
Visualization of air pressure



Front visualization

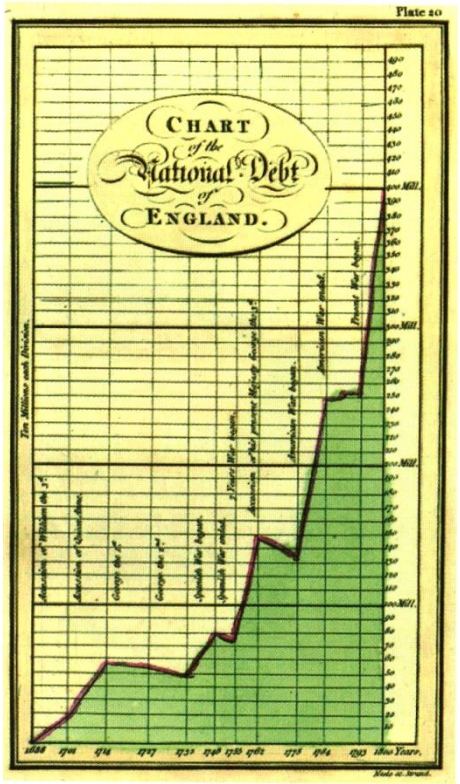


Maps for pilots

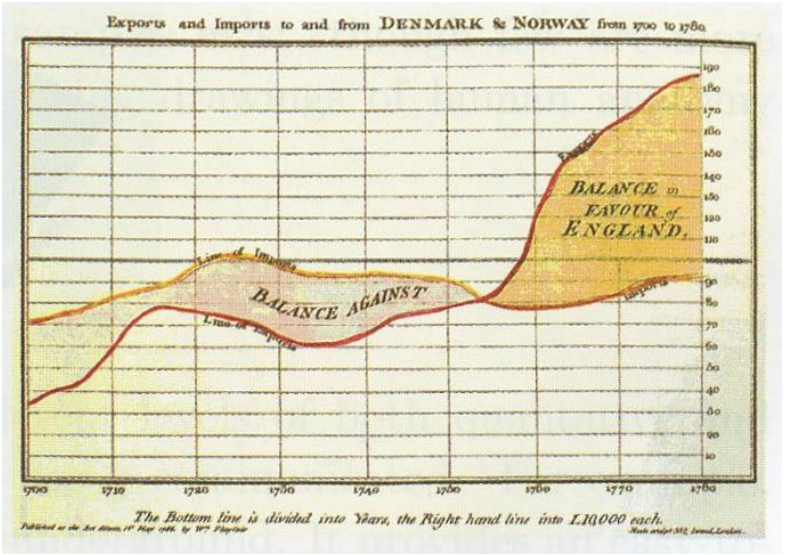


Business visualization

- Using two axes



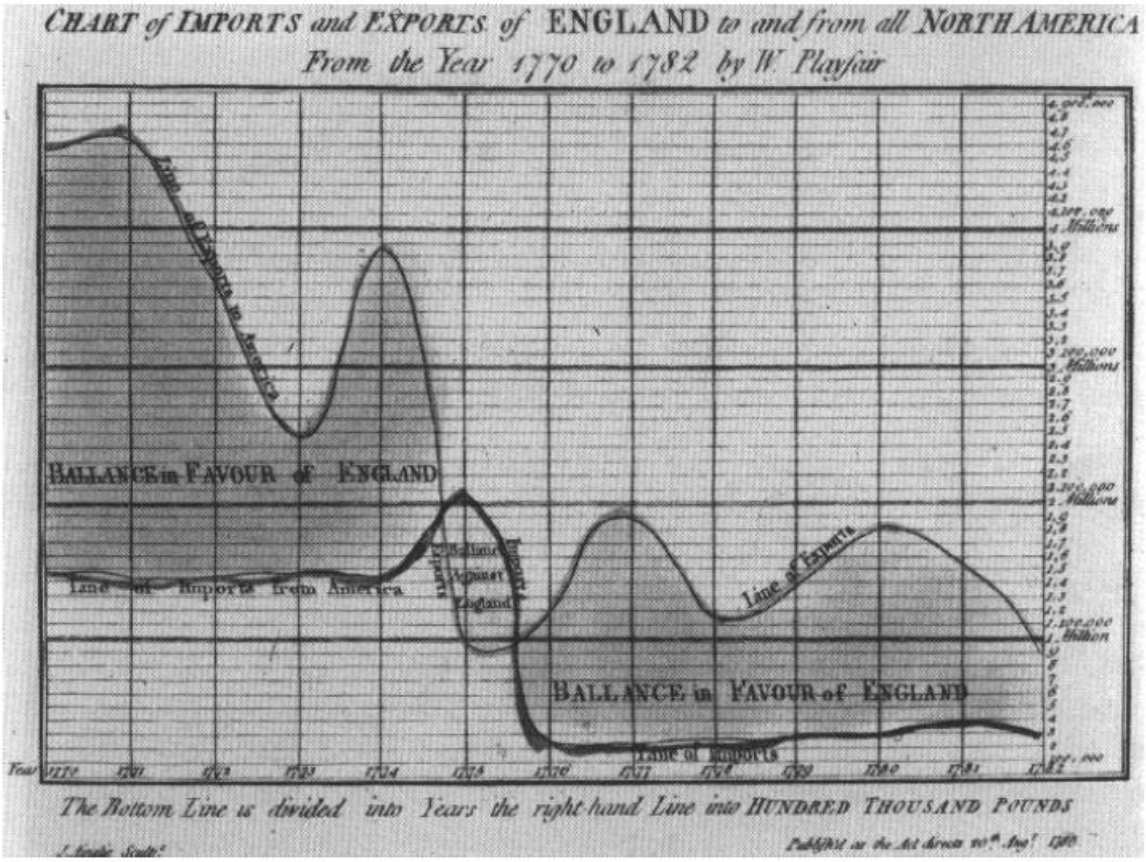
National debt of England
(William Playfair)



Business development between England and Norway and Denmark (1786)

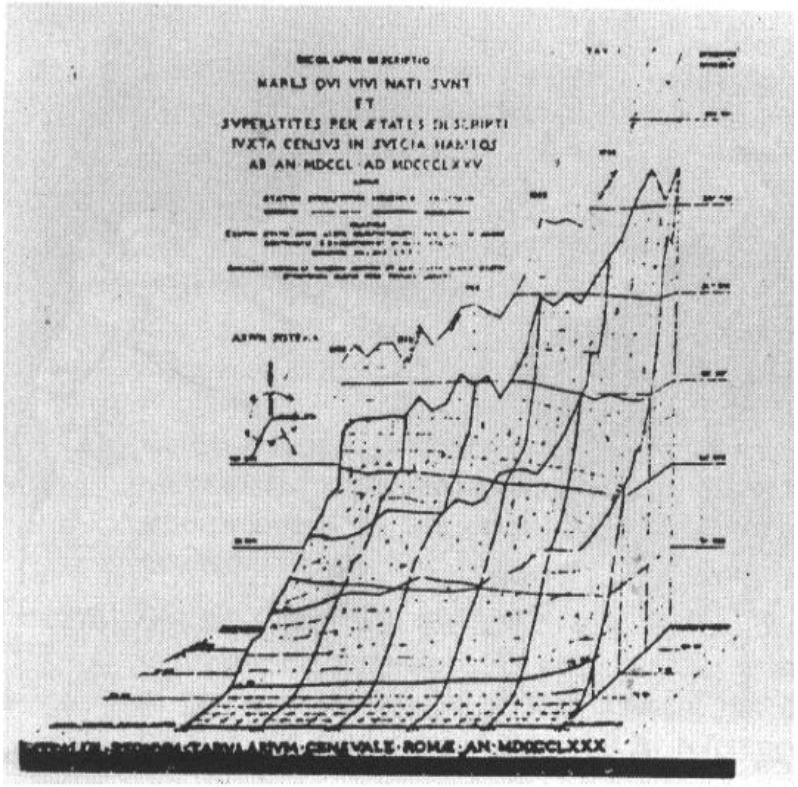
Business visualization

- W. Playfair: import/export USA-England, 1770-1782



Population development

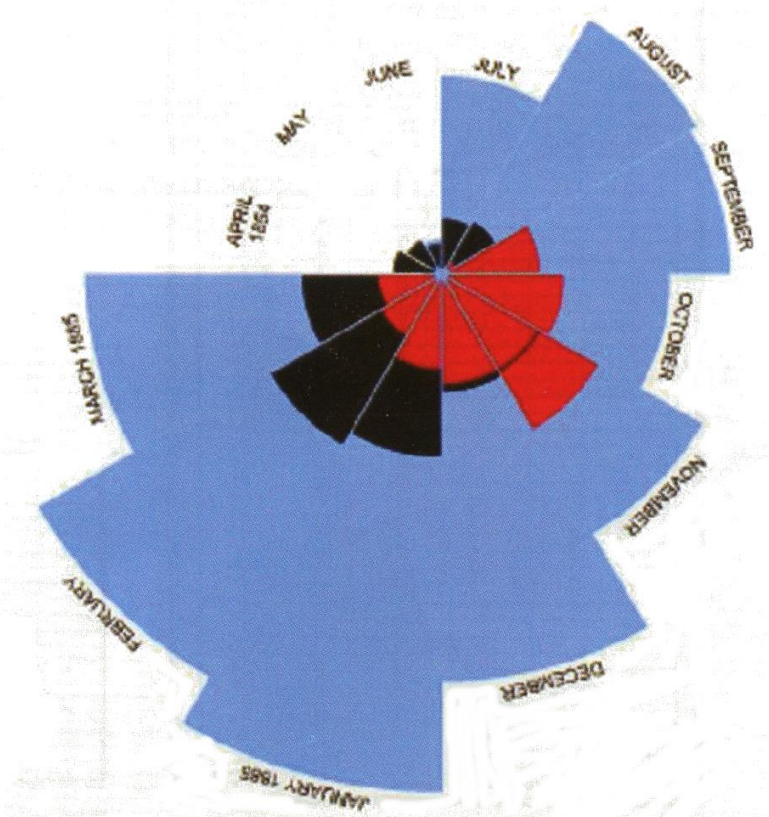
- Population size in Sweden 1750 – 1785
- Axes represent year and age category



History

- Graph shows the mortality in army between 04/1854 and 05/1855

  (Florence Nightingale)
- Blue – sickness
- Red – injury
- Black - other



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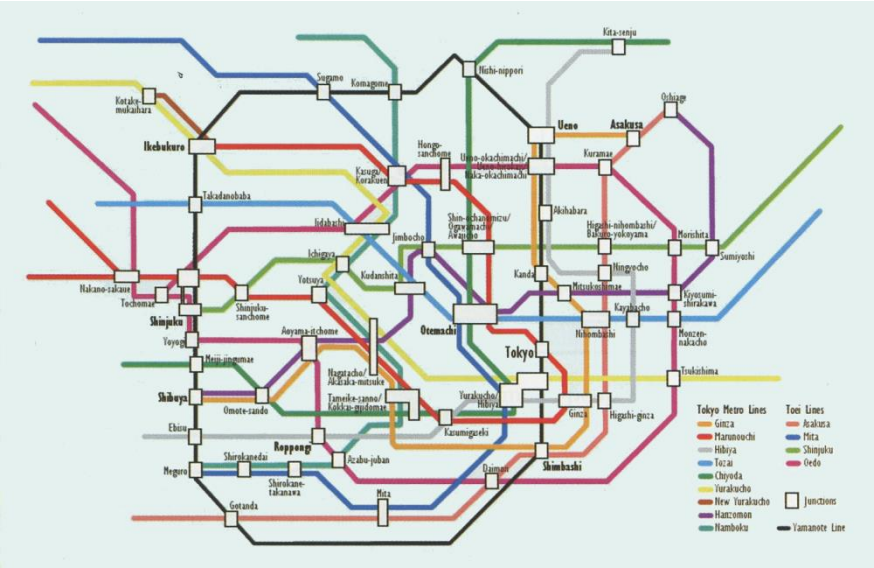
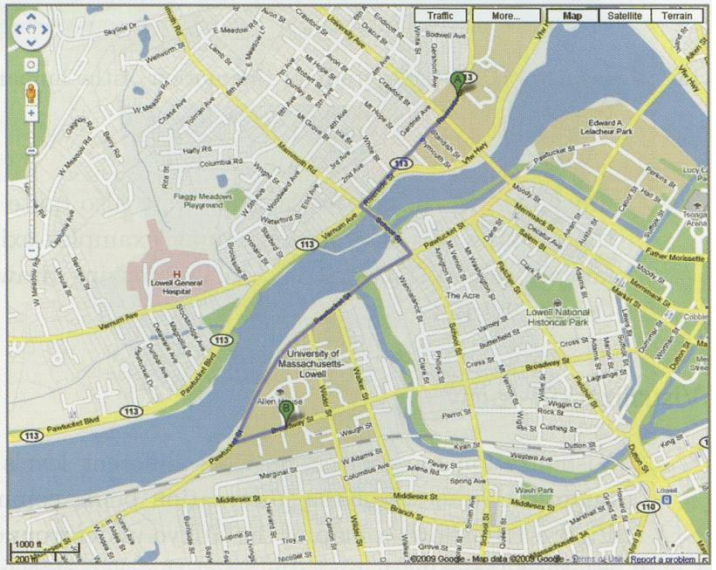
Visualization „today“

- 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



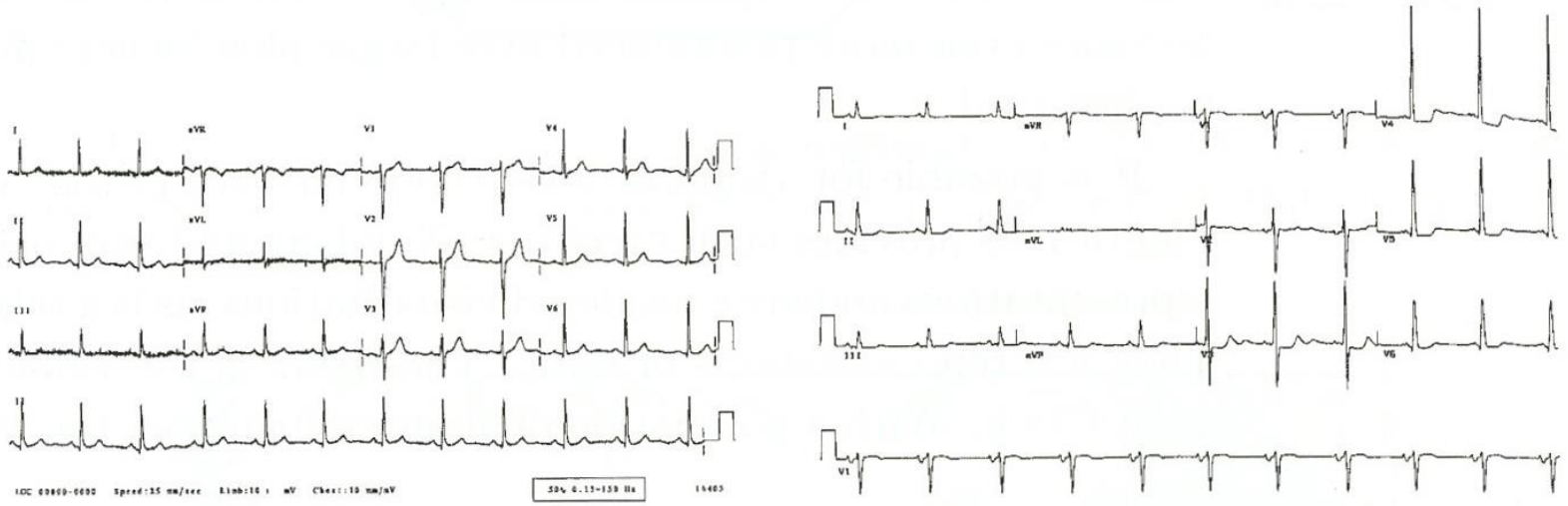


Visualization today

- Data can be visualized precisely

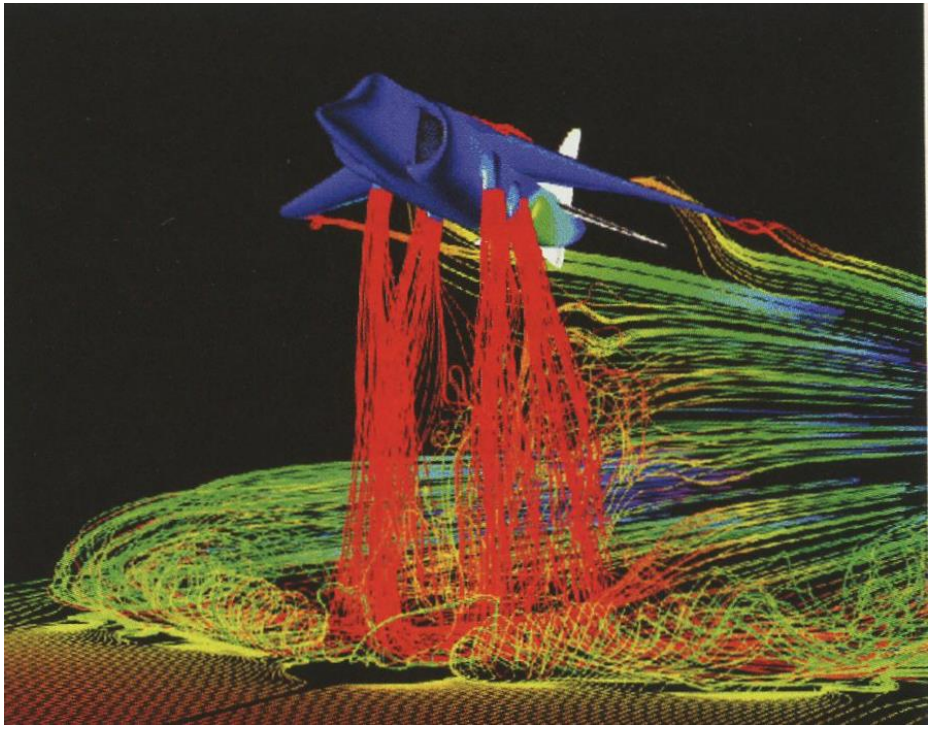
$11,956,584,748,608.58

- Fast identification of problem



Visualization today

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



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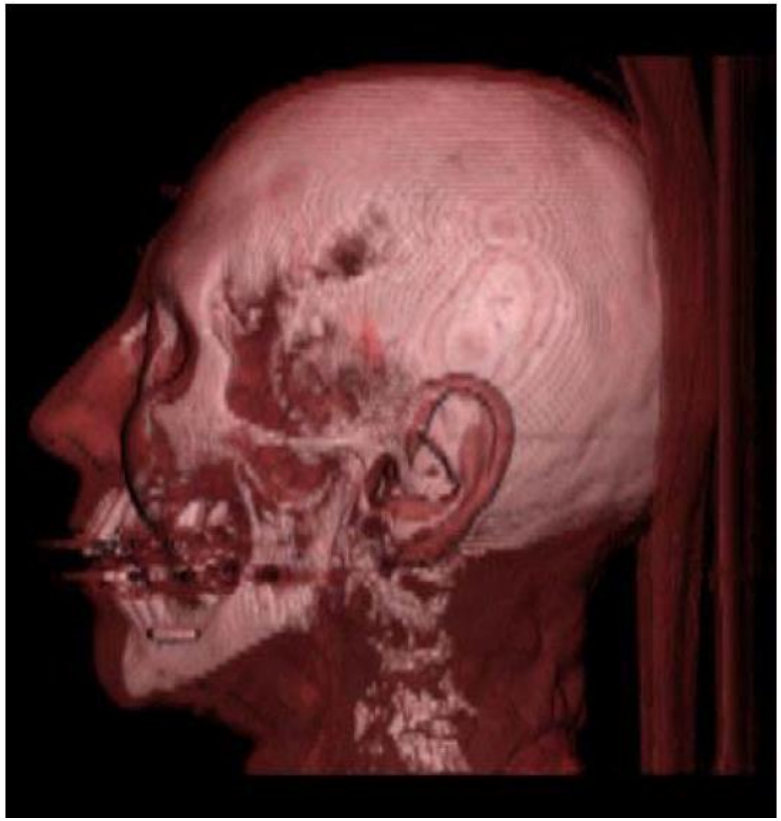
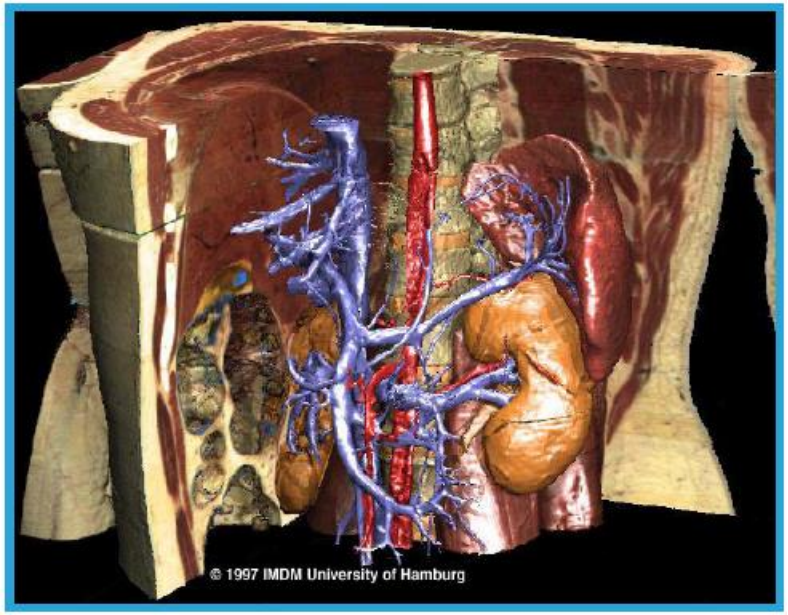
Visualization today

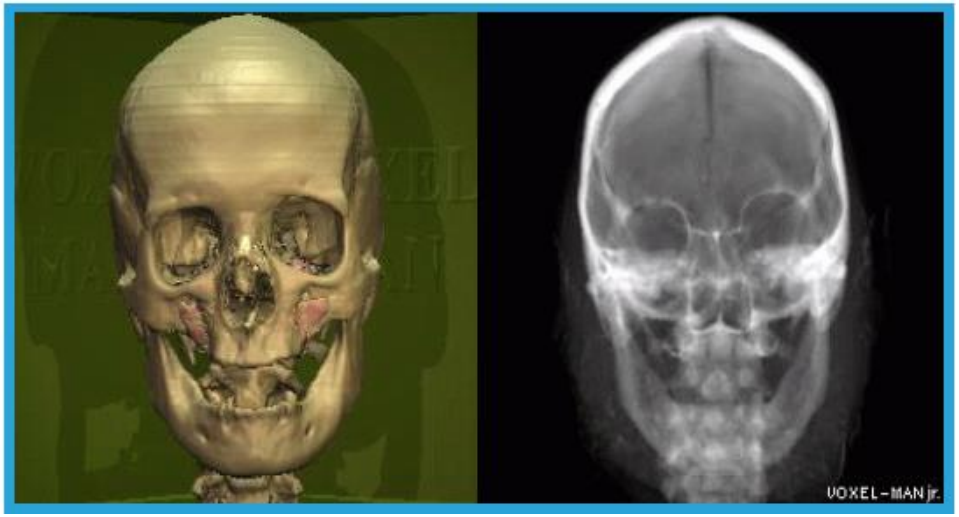
- Medical data (MedVis, VolVis)
- Flow data (FlowVis)
- Abstract data (InfoVis)
- GIS data
- Historical data (archeology)
- Microscopic data (molecular physics)
- Macroscopic data (astronomy)
- Big data

…

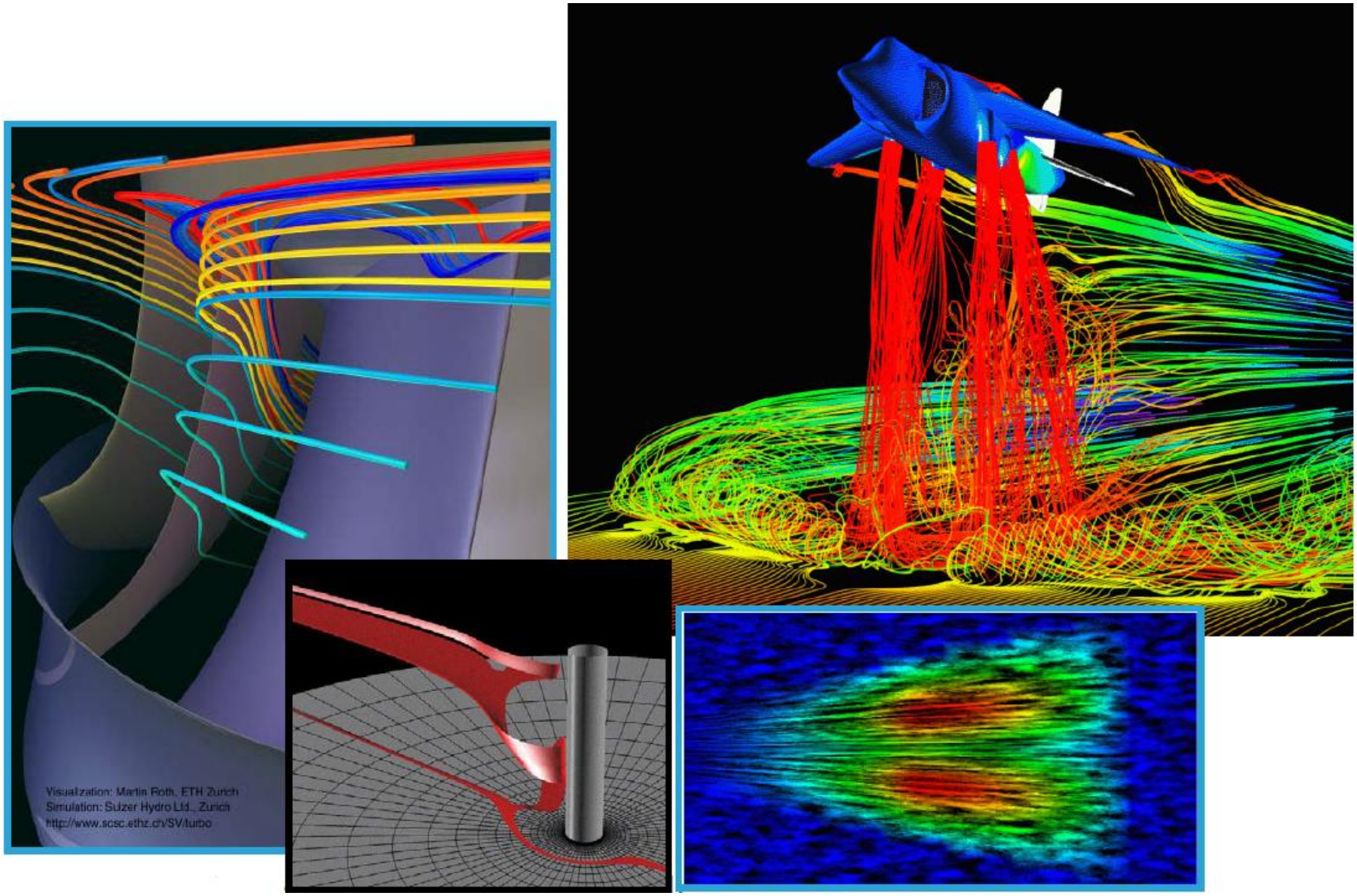
Medical visualization



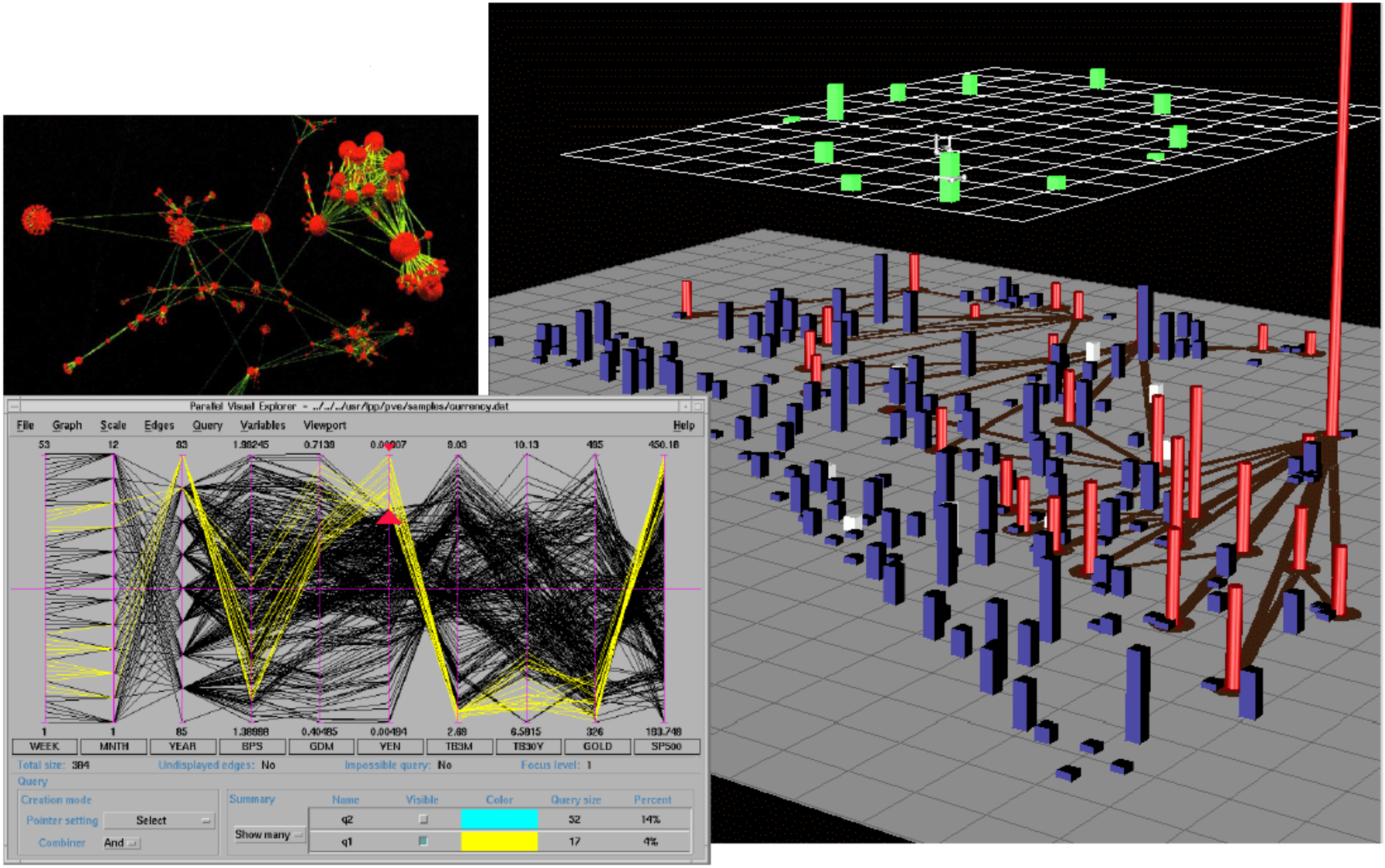




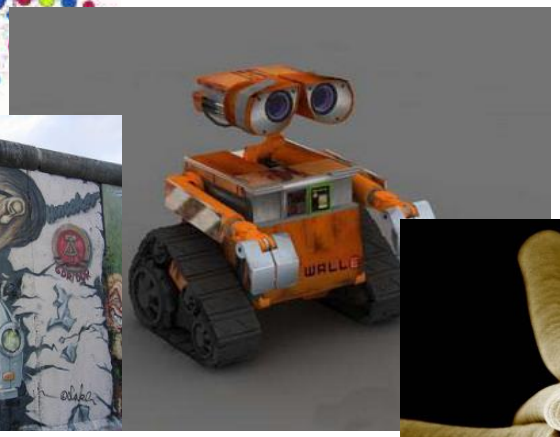
Flow visualization

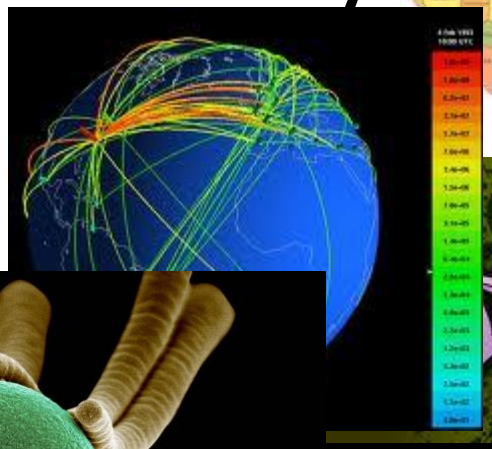
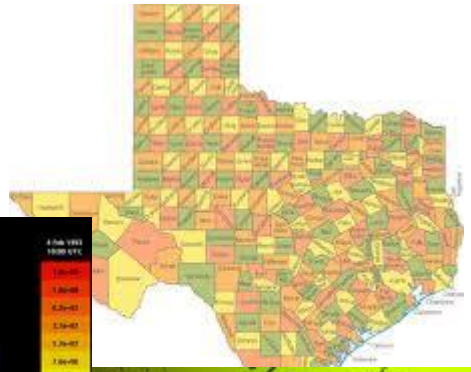


Abstracted visualization

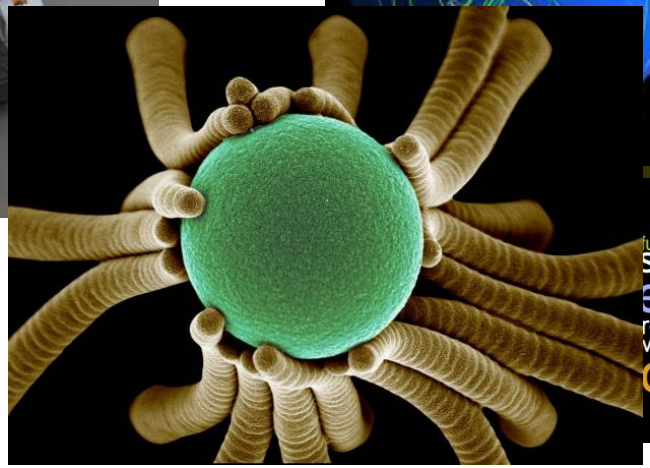


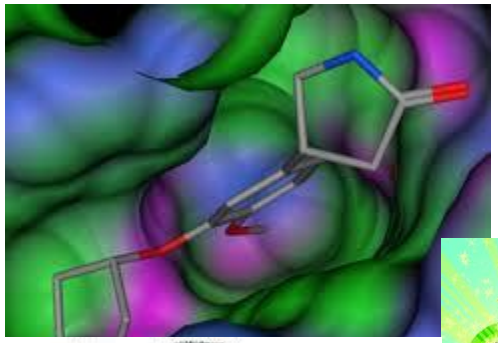
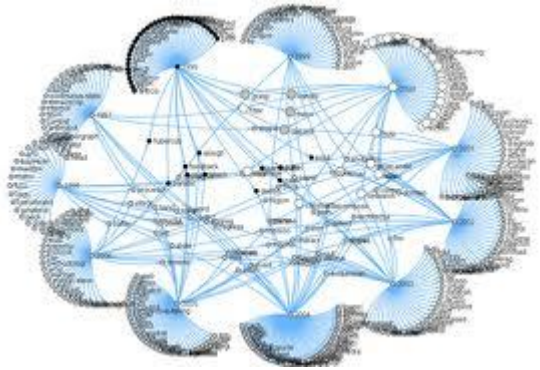
Visualization today

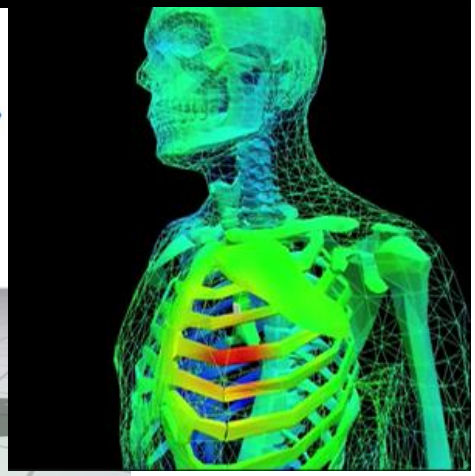









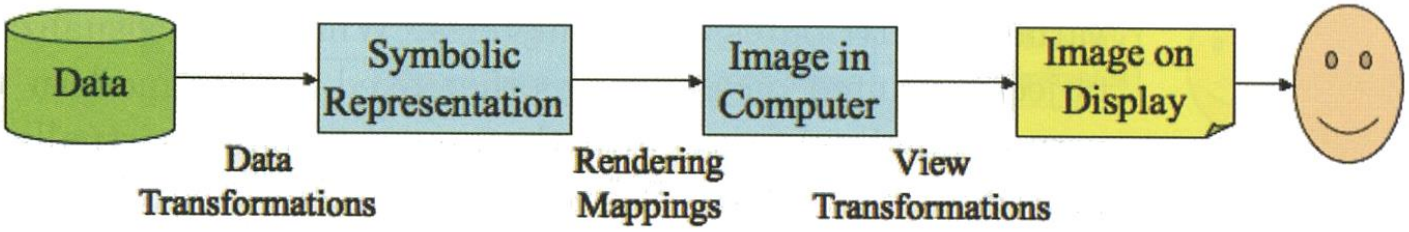
Visualization vs. computer graphics

- 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

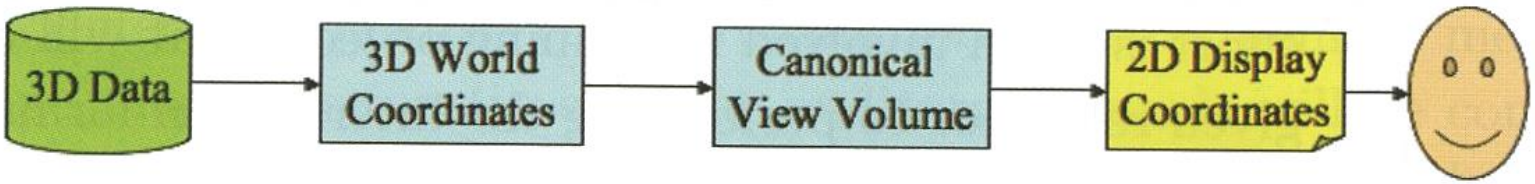
- Input data analysis
- Input requirements analysis
- Mapping data onto screen



- Enabling interactive manipulation

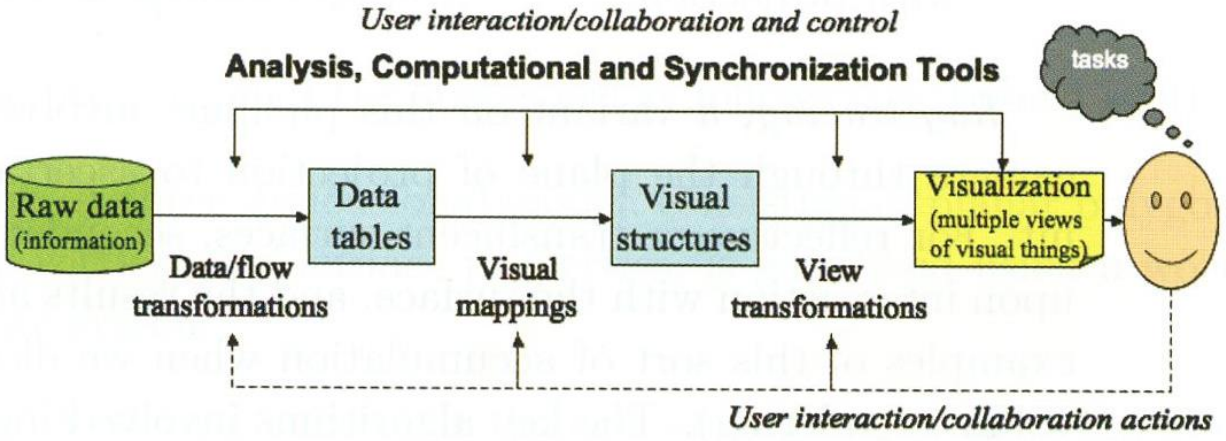
CG Pipeline

- 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

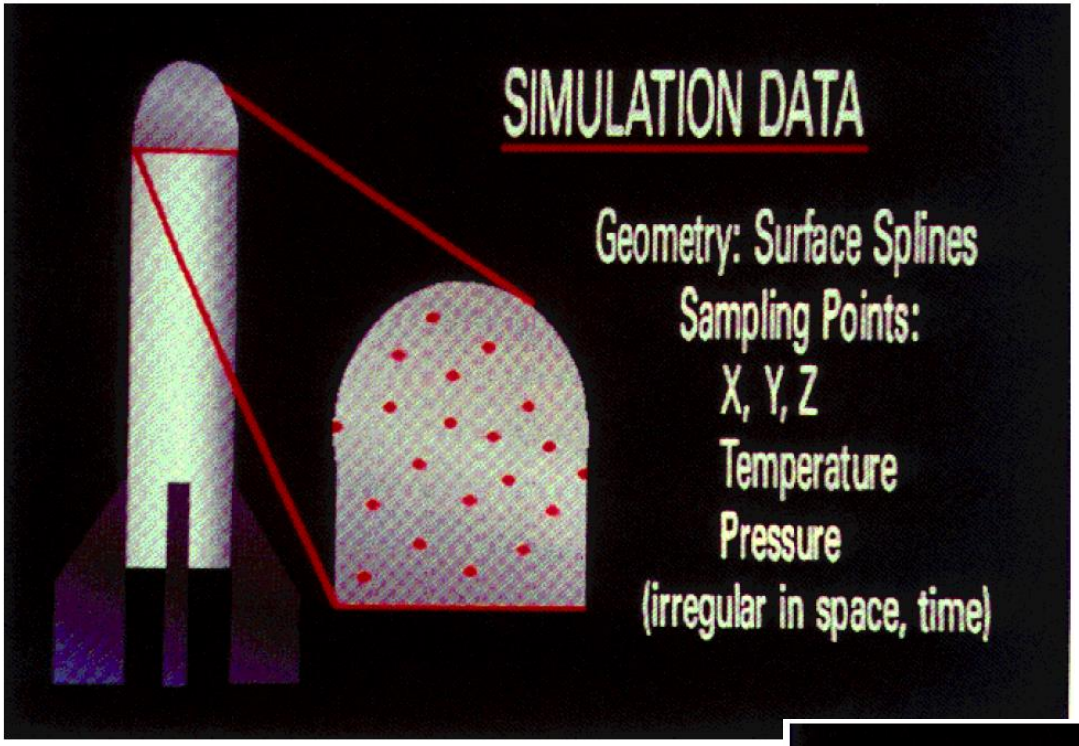
- Data are mapped to the representation suitable for rendering (e.g., geometry)
  - Computation of isosurfaces
  - Mapping to glyphs, icons
  - Computation of the distribution of data in a graph
  - Determining the attributes of voxel data (color, transparency, …)

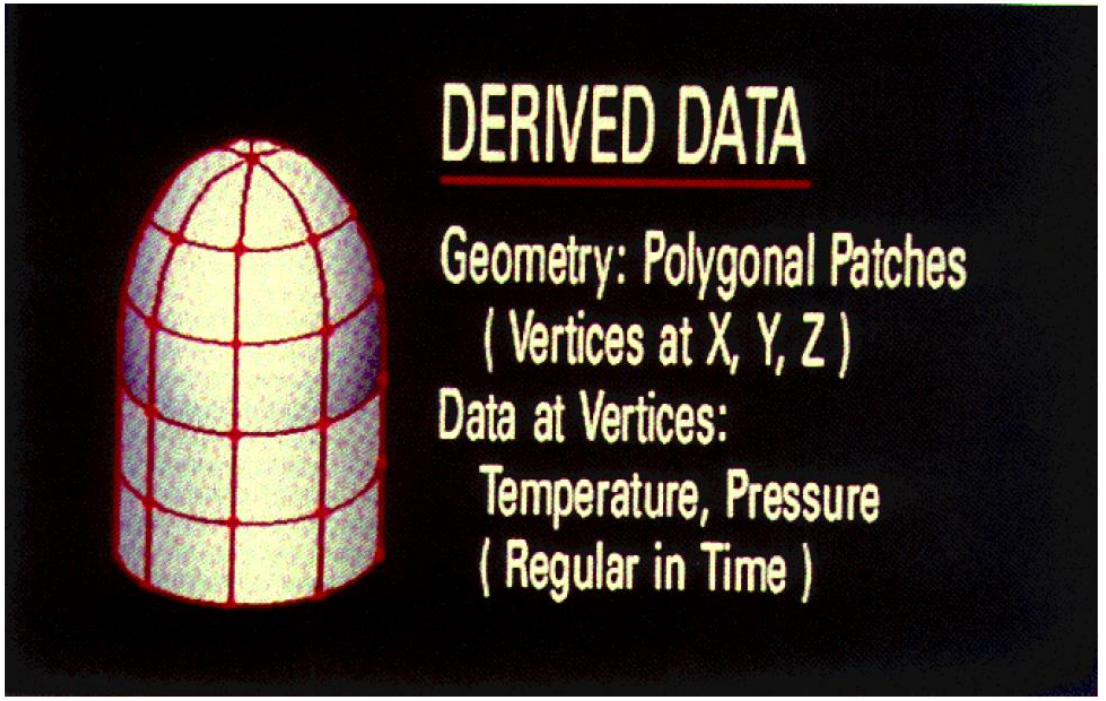
  …

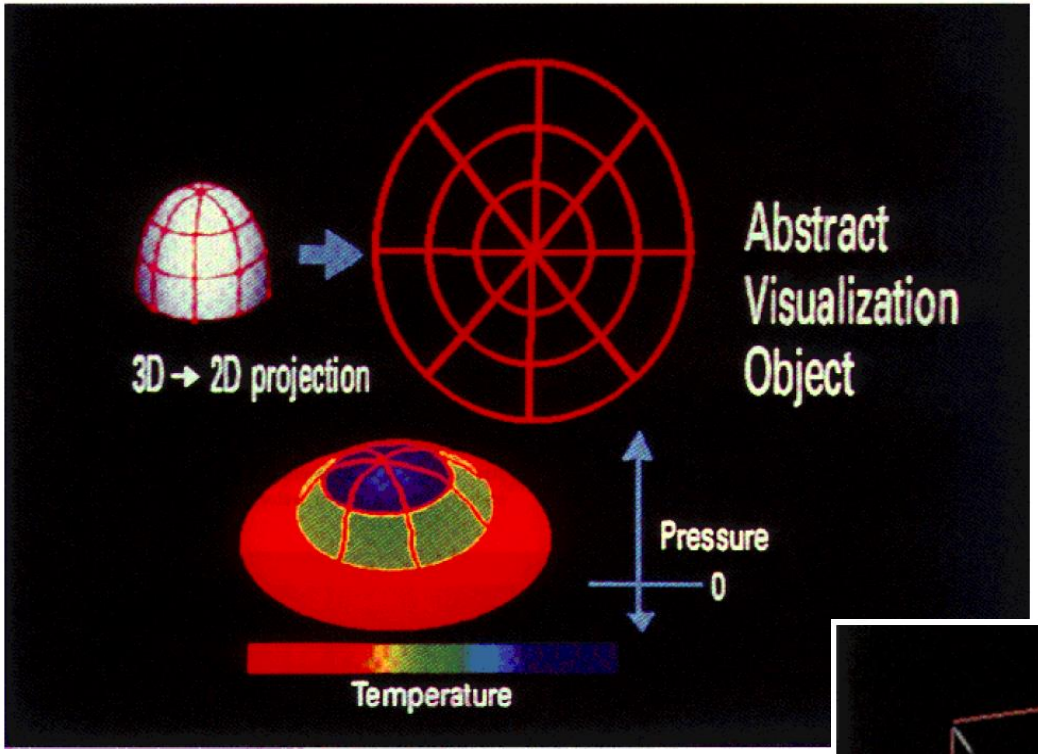
Generating images

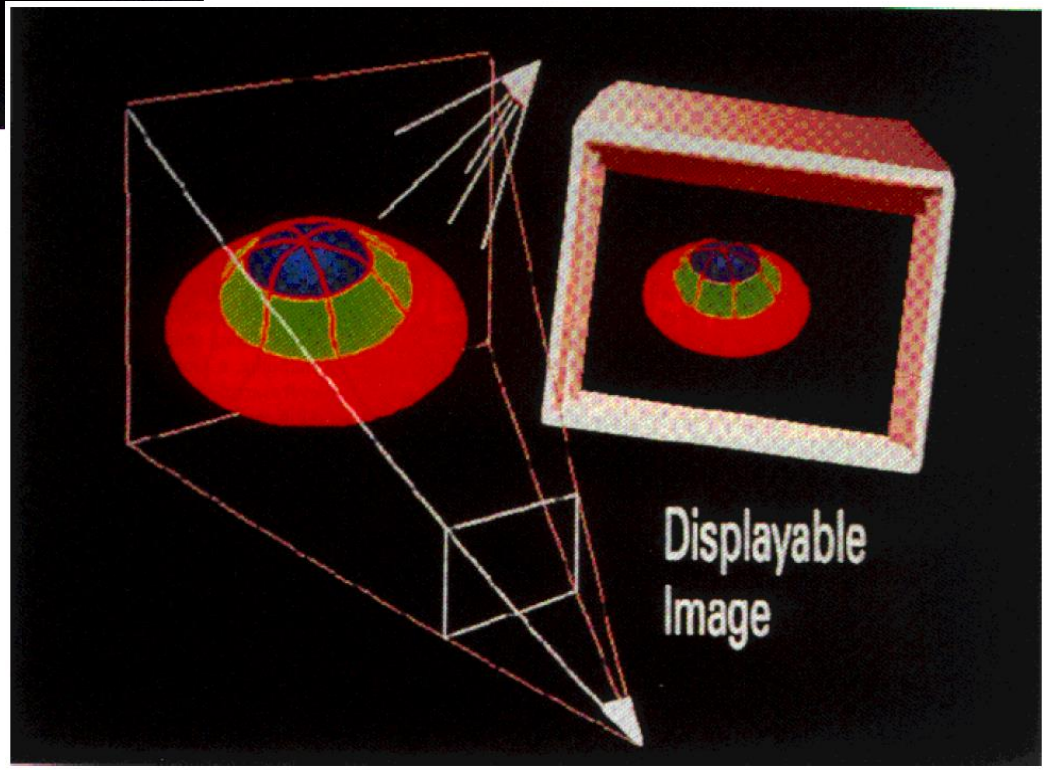
- Using computer graphics principles
  - Visibility computation
  - Lighting
  - Alpha blending
  - Animation

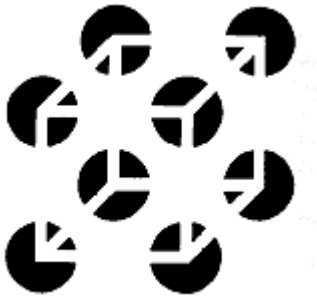
    …


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)


3D → 2D projection
Abstract
Visualization
Object
Pressure
0
Temperature


Displayable
Image



cat.rulez.cz

www.yorksir.estranky.cz

Human cognition and processing of information

www.quertime.com

appsychtextbk.wikispaces.com

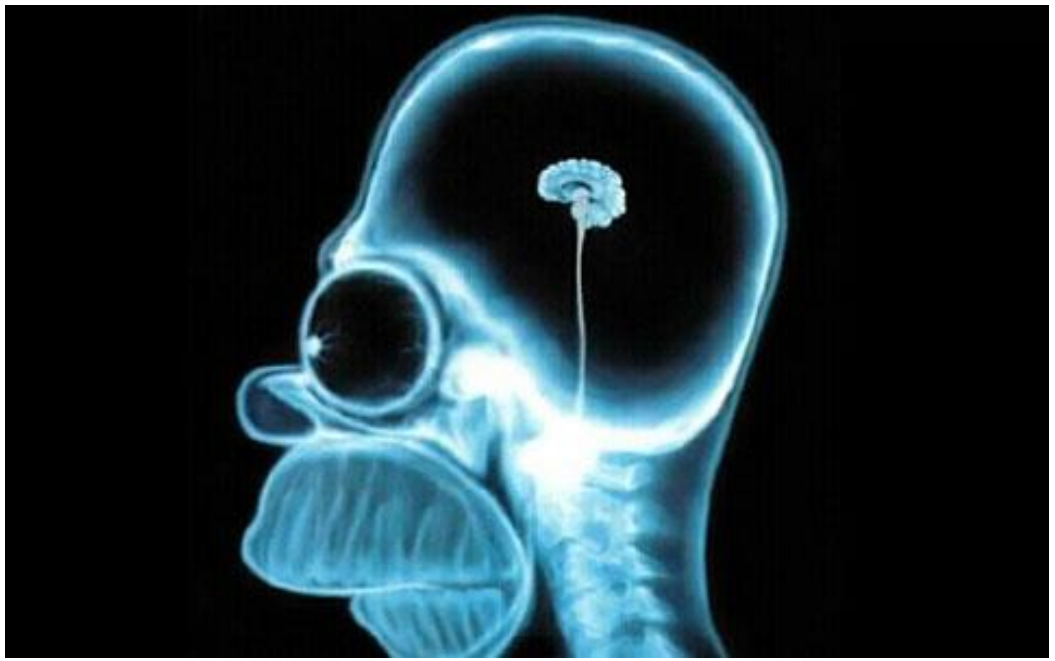
Human cognition

- 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

www.gearfuse.com

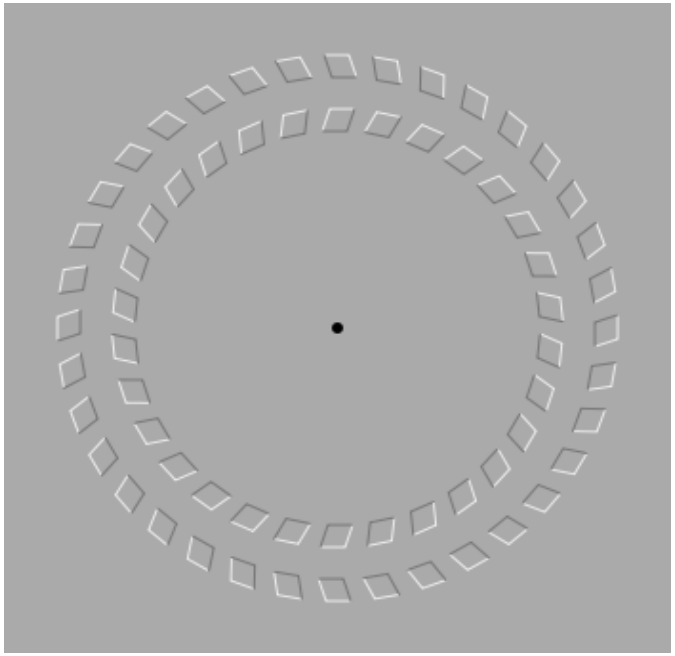
Human cognition

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

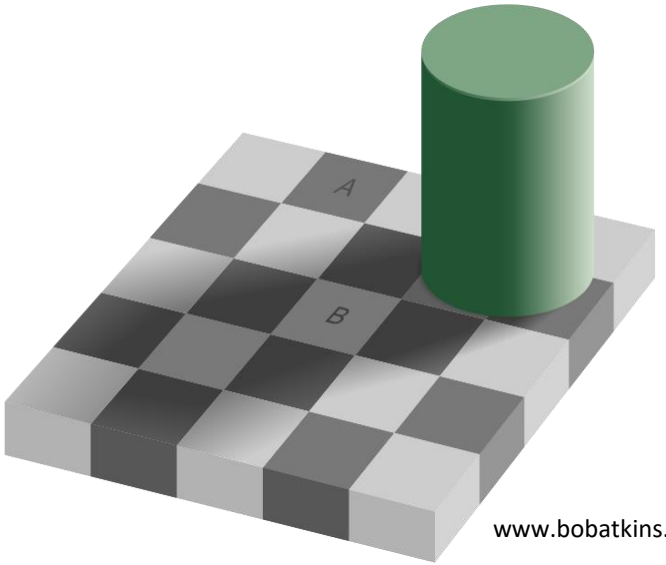


www.ranker.com

Targeted desinterpretation – optical illusions



library.thinkquest.org

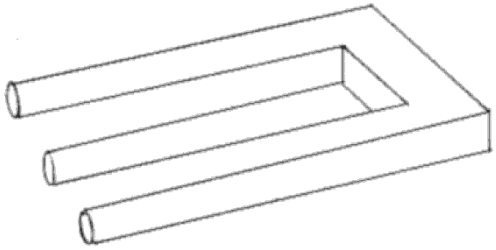


www.bobatkins.com

www.roumazeilles.net

Optical illusions

opticalillusionpictures.net

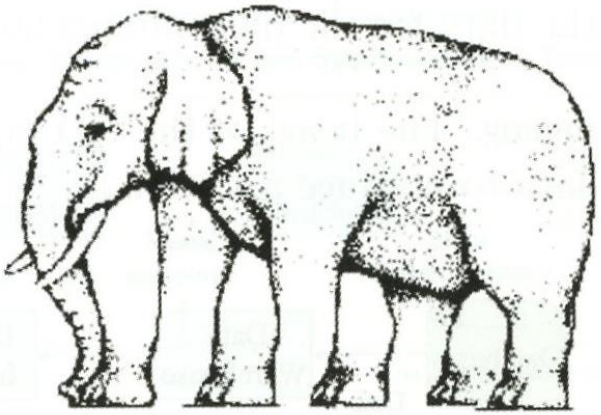


listverse.com

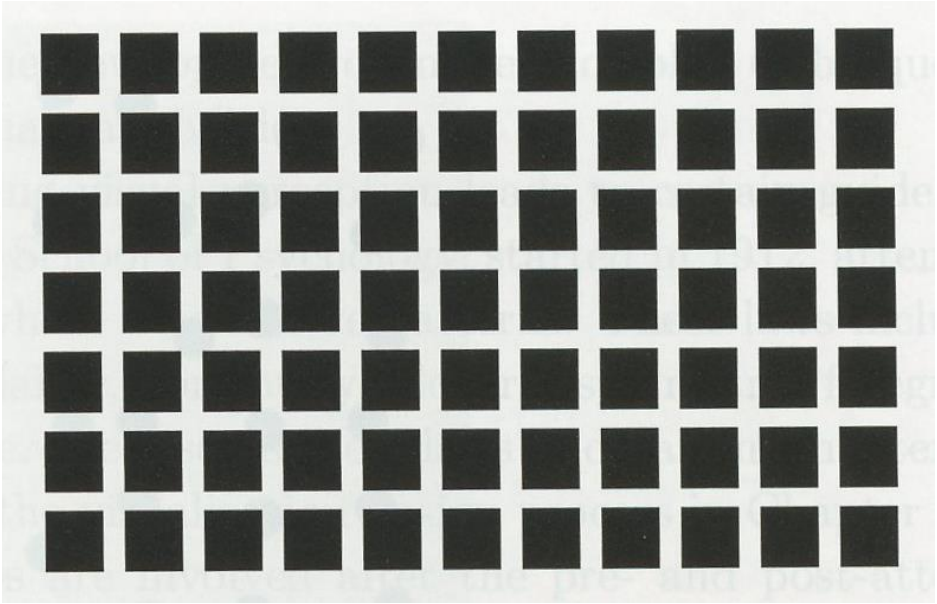
3d-pictures.feedio.net

Human cognition

- Sight is very limited



thinkoutsidetheboxtoday.com

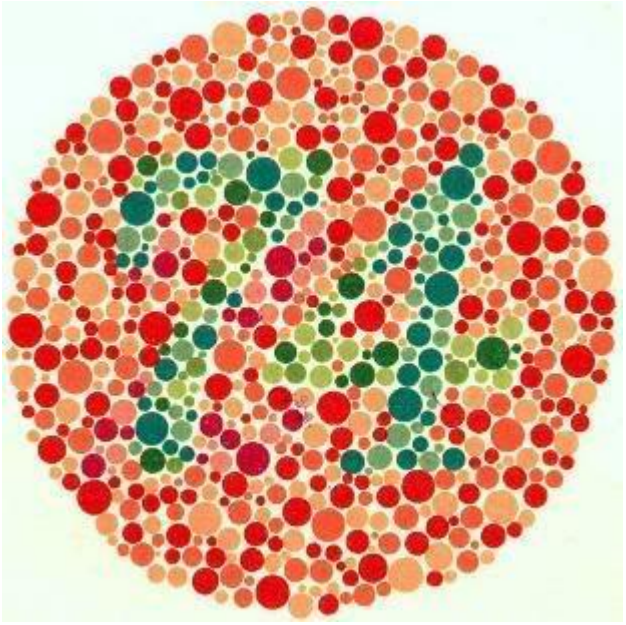


www.brainist.com

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

- Color
- Texture
- Movement

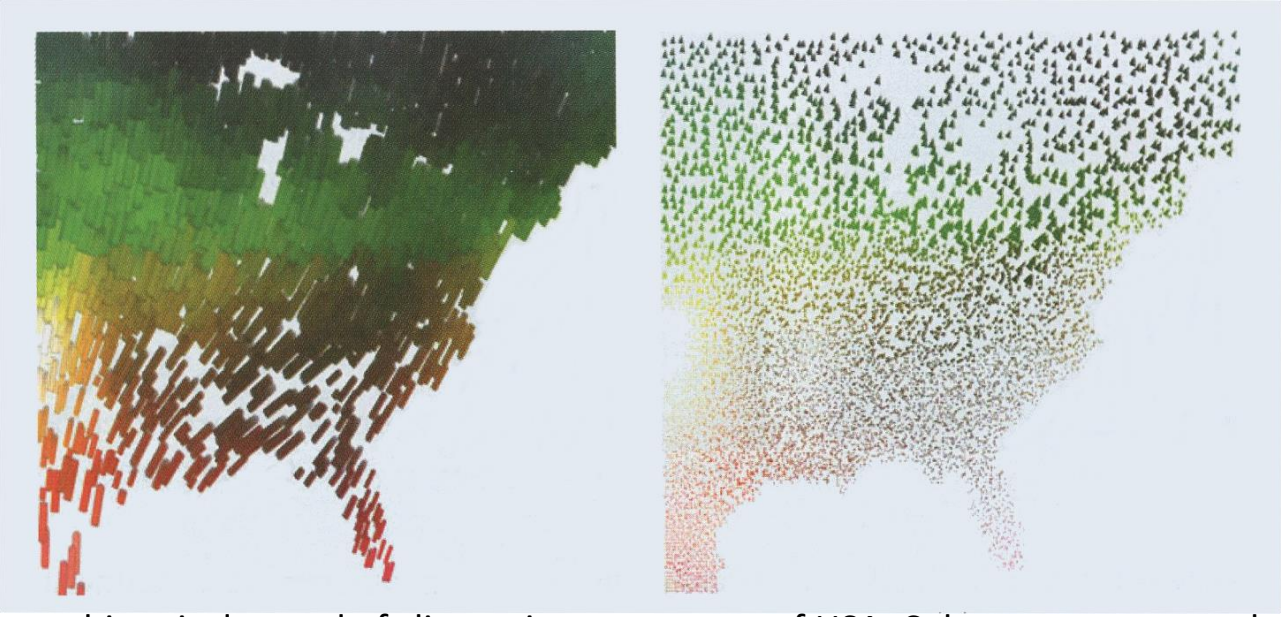
www.streetartutopia.com

cz.123rf.com

blog.experimentsinmotion.com

Color

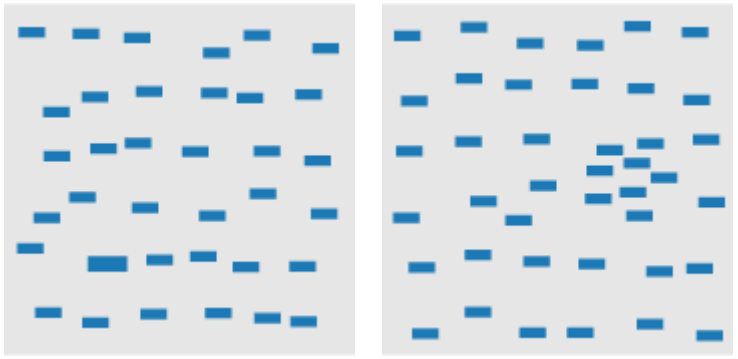
- Color balance – uniform distribution of color values in the whole range
- Distinguishability – in a given discrete palette each color has to be similarly distinguishable from the others
- Flexibility – colors can be selected from any place of the color space used



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

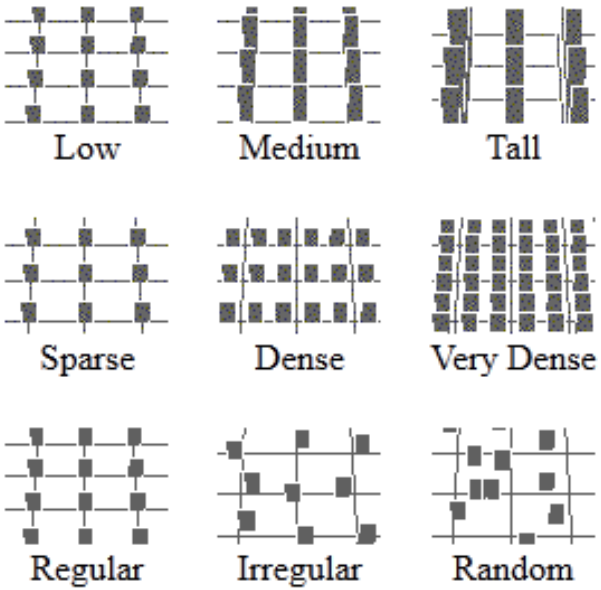
- Healey and Enns – pexels (perceptual texture elements)
- Size and density are well perceivable, variations in regularity are perceived worse

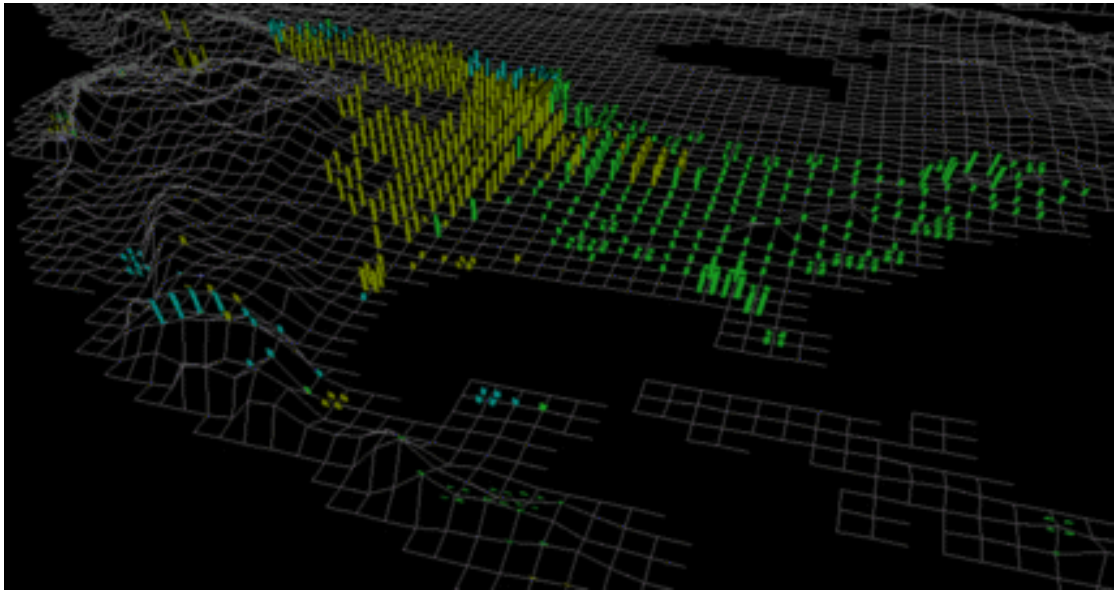


www.csc.ncsu.edu

Texture

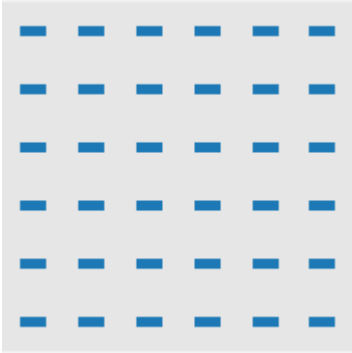
- Pexel can have 3 discrete values (height, density, randomness)
- Visualization of areas with large land cultivation (height = degree of cultivation, density = type of soil, randomness = crop type)





Movement

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



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

flicker

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

Examples

- Perceptually uniform motion space
  - http://openaccess.city.ac.uk/3752/1/Perceptually%20Uniform%20Motion%20Space.pdf
- Attractive flicker
  - https://www.cg.tuwien.ac.at/research/publications/2014/waldner-2014-af/waldner-2014-af-Submission%20video.mp4