CS 247 – Scientific Visualization
Lecture 2: Introduction, Pt. 2

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Reading Assignment #1 (until Feb 1)

Sign up for piazza!
http://piazza.com/kaust.edu.sa/spring2021/cs247

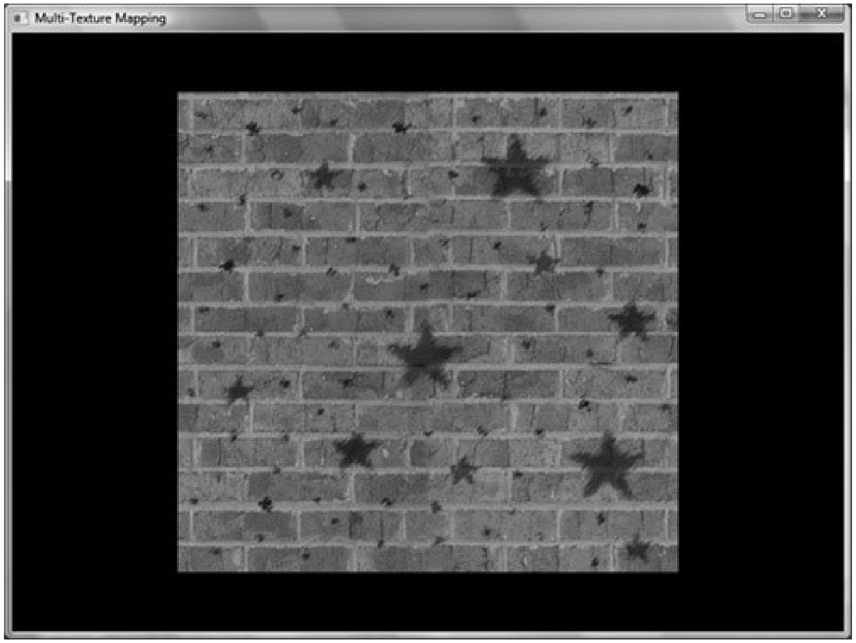
Read (required):

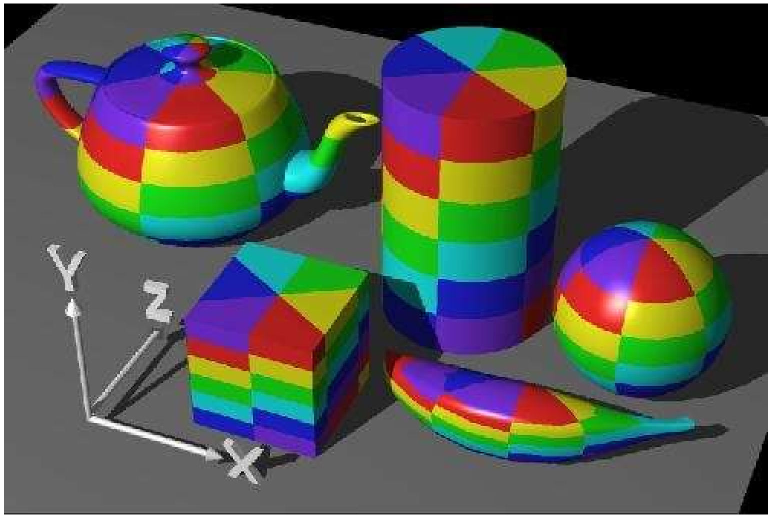
- Data Visualization book, Chapter 1
- Data Visualization book, Chapter 2 until 2.4 (inclusive)
- Download and look at:
  NIH/NSF Visualization Research Challenges report

  `https://gvi.seas.harvard.edu/sites/all/files/NIH-NSF-VRC-Report.pdf`

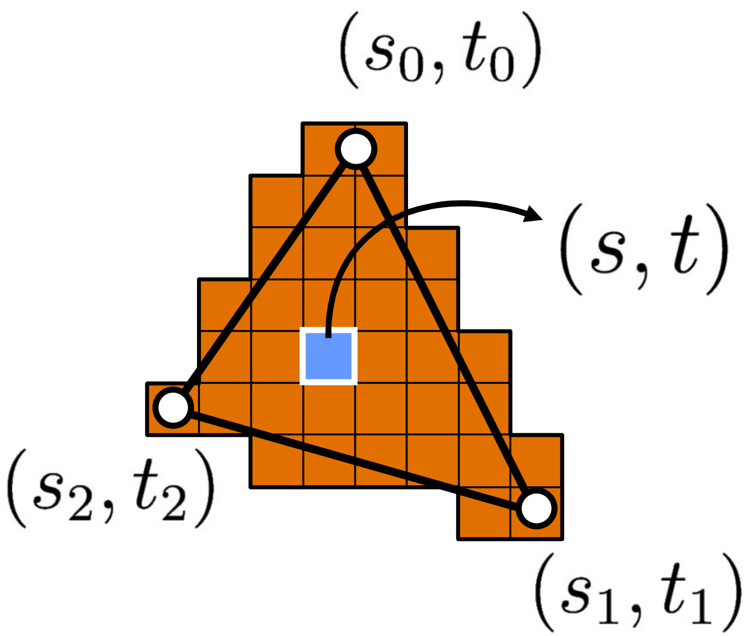
- Start familiarizing yourself with OpenGL if you do not know it !

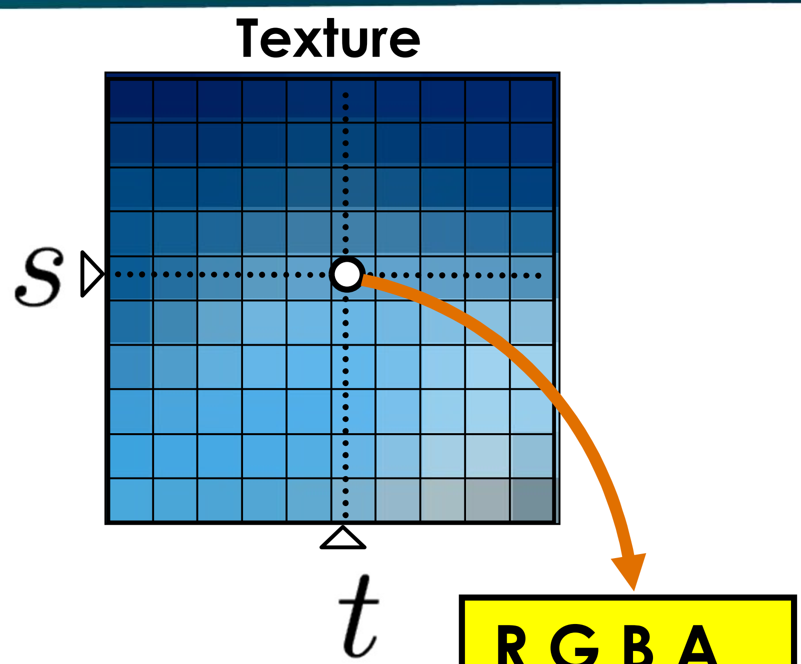
Texture Mapping





2D Texture Mapping

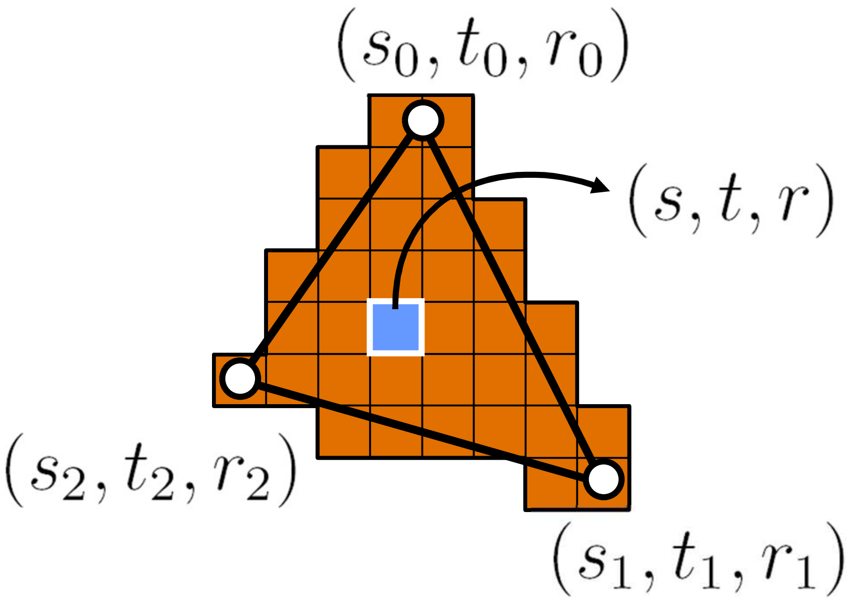


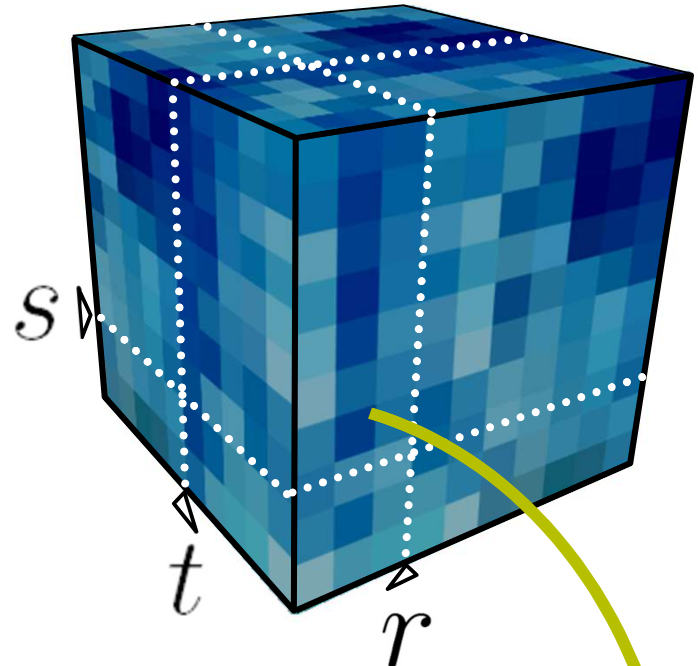


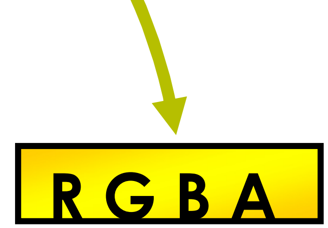
For each fragment:
interpolate the
texture coordinates
(barycentric)
Or:
Use arbitrary, computed coordinates

Texture-Lookup:
interpolate the
texture data
(bi-linear)
Or:
Nearest-neighbor for "array lookup"

3D Texture Mapping







For each fragment:
interpolate the
texture coordinates
(barycentric)
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Use arbitrary, computed coordinates

Texture-Lookup:
interpolate the
texture data
(tri-linear)
Or:
Nearest-neighbor for "array lookup"

What is Scientific Visualization? (1)

The use of computer graphics for the analysis and presentation of computed or measured scientific data

- Started in 1987 by the US National Science Foundation (NSF) in the “Visualization in Scientific Computing“ report

  `https://www.evl.uic.edu/pubs/1501`

- First IEEE Visualization conference 1990
- 2006 NIH/NSF Visualization Research Challenges Report, Chris Johnson et al.

  `https://gvi.seas.harvard.edu/sites/all/files/NIH-NSF-VRC-Report.pdf`

“The purpose of computing is insight, not numbers“
Richard Hamming, 1971

What is Scientific Visualization? (2)

Visualization is a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualization offers a method for seeing the unseen. It enriches the process of scientific discovery and fosters profound and unexpected insights. In many fields it is already revolutionizing the way scientists do science.

McCormick, B.H., T.A. DeFanti, M.D. Brown,
Visualization in Scientific Computing,
Computer Graphics 21(6), November 1987

What is Scientific Visualization? (3)

The standard argument to promote scientific visualization is that today's researchers must consume ever higher volumes of numbers that gush, as if from a fire hose, out of supercomputer simulations or high-powered scientific instruments. If researchers try to read the data, usually presented as vast numeric matrices, they will take in the information at snail's pace. If the information is rendered graphically, however, they can assimilate it at a much faster rate.

R.M. Friedhoff and T. Kiely,
The Eye of the Beholder,
Computer Graphics World 13(8), pp. 46-, August 1990

What is Scientific Visualization? (4)

The use of computer imaging technology as a tool for comprehending data obtained by simulation or physical measurement by integration of older technologies, including computer graphics, image processing, computer vision, computer-aided design, geometric modeling, approximation theory, perceptual psychology, and user interface studies.

R.B. Haber and D. A. McNabb,

Visualization Idioms: A Conceptual Model for Scientific Visualization Systems,
Visualization in Scientific Computing,
IEEE Computer Society Press 1990.

What is Scientific Visualization? (5)

Scientific Visualization is concerned with exploring data and information in such a way as to gain understanding and insight into the data. The goal of scientific visualization is to promote a deeper level of understanding of the data under investigation and to foster new insight into the underlying processes, relying on the humans' powerful ability to visualize. In a number of instances, the tools and techniques of visualization have been used to analyze and display large volumes of, often time-varying, multidimensional data in such a way as to allow the user to extract significant features and results quickly and easily.

K.W. Brodlie, L.A. Carpenter, R.A. Earnshaw, J.R. Gallop, R.J. Hubbard, A.M. Mumford, C.D. Osland, P. Quarendon, ***Scientific Visualization, Techniques and Applications**, Springer-Verlag, 1992.*

What is Scientific Visualization? (6)

Scientific data visualization supports scientists and relations,

to prove or disprove hypotheses, and discover new phenomena

using graphical techniques.

The primary objective in data visualization is to gain insight into

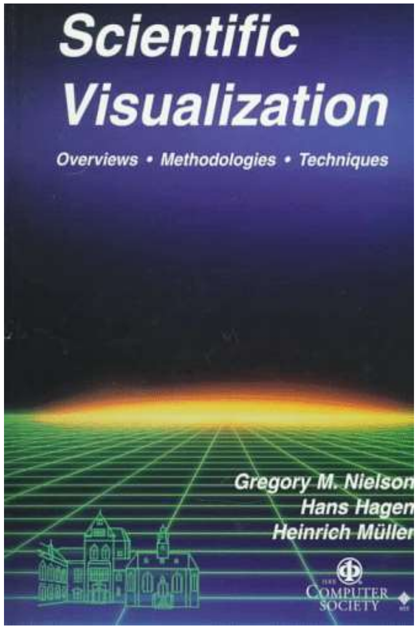
an information space by mapping data onto graphical primitives.

H. Senay and E. Ignatius,
A Knowledge-Based System for Visualization Design,
IEEE Computer Graphics and Applications, pp. 36-47, November 1994

Visualization – Background

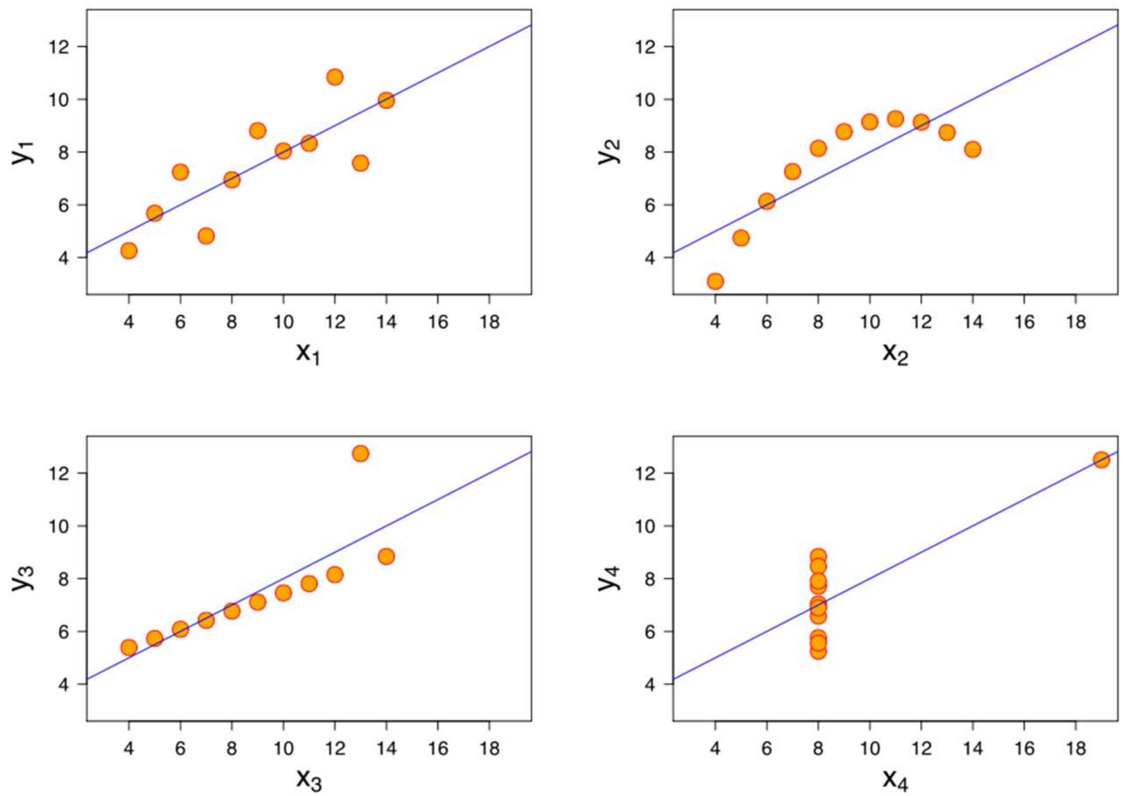
Leonardo da Vinci (1452-1519)

- Visualization in general: quite old
- Often an intuitive step: graphical illustration
- Data with ever increasing sizes ⇒ graphical approach necessary
- Simple approaches known from business graphics (Grapher, Excel, etc.)
- Visualization: scientific discipline since ~1987
- First dedicated conferences: 1990



1997

Example: Anscombe's Quartet



Francis Anscombe, 1973

https://en.wikipedia.org/wiki/Anscombe%27s_quartet

→ Exploratory Data Analysis (EDA), John Tukey, 1977

Visualization – Three Types of Goals

Visualization, …

- … to explore
  - nothing is known,
    visualization used for data exploration
- … to analyze
  - there are hypotheses,
    visualization used for verification or falsification
- … to present
  - “everything” known about the data,
    visualization used for communication of results

Visualization – Major Areas

Four major areas

Inherent spatial reference

- Volume Visualization
- Flow Visualization

} Scientific Visualization

3D

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nD

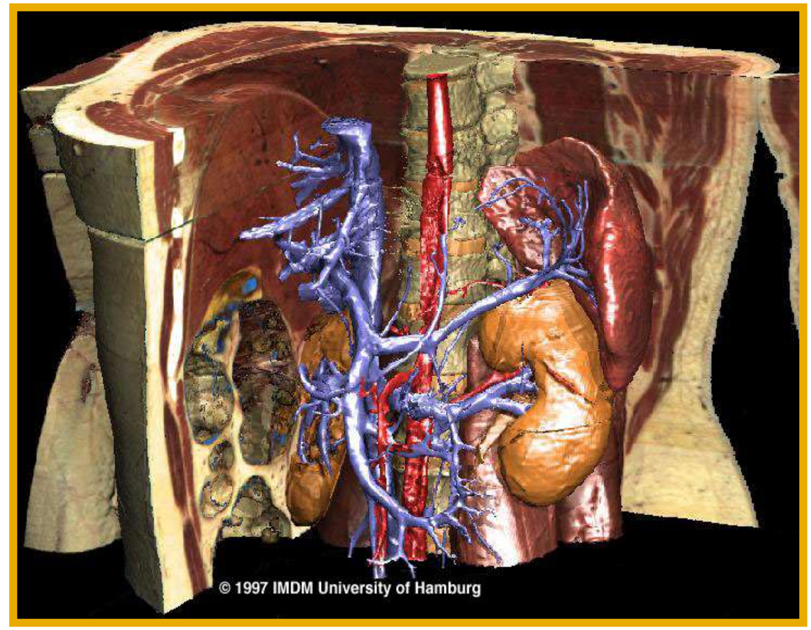
- Information Visualization
- Visual Analytics

Usually no spatial reference

But these lines are becoming more and more blurred!

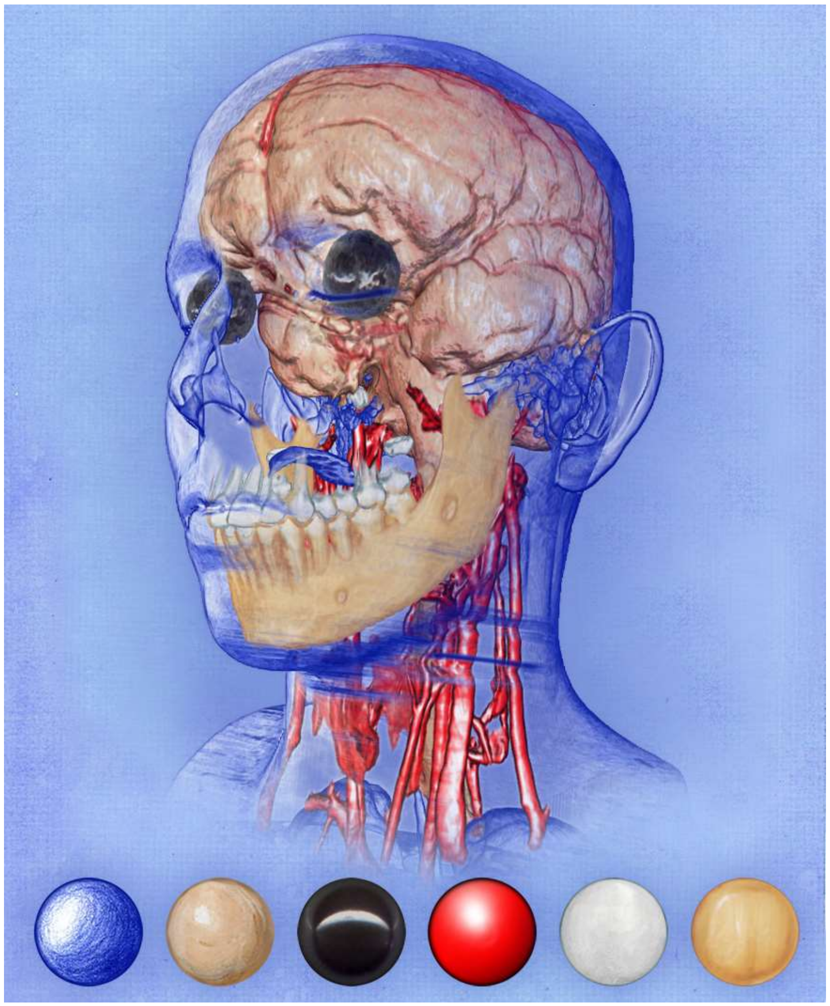
Scientific Visualization – Examples

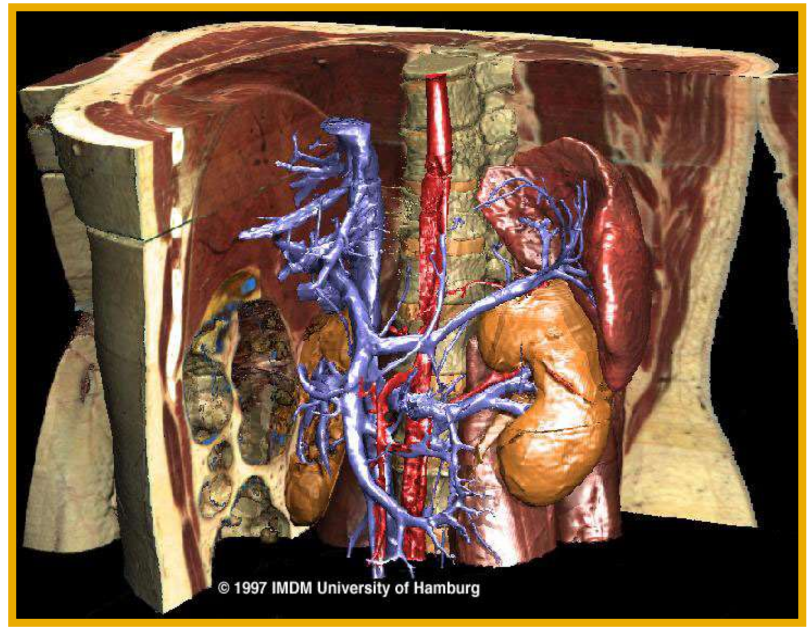
Medical data (CT, MR, DSA, PET, …)



Scientific Visualization – Examples

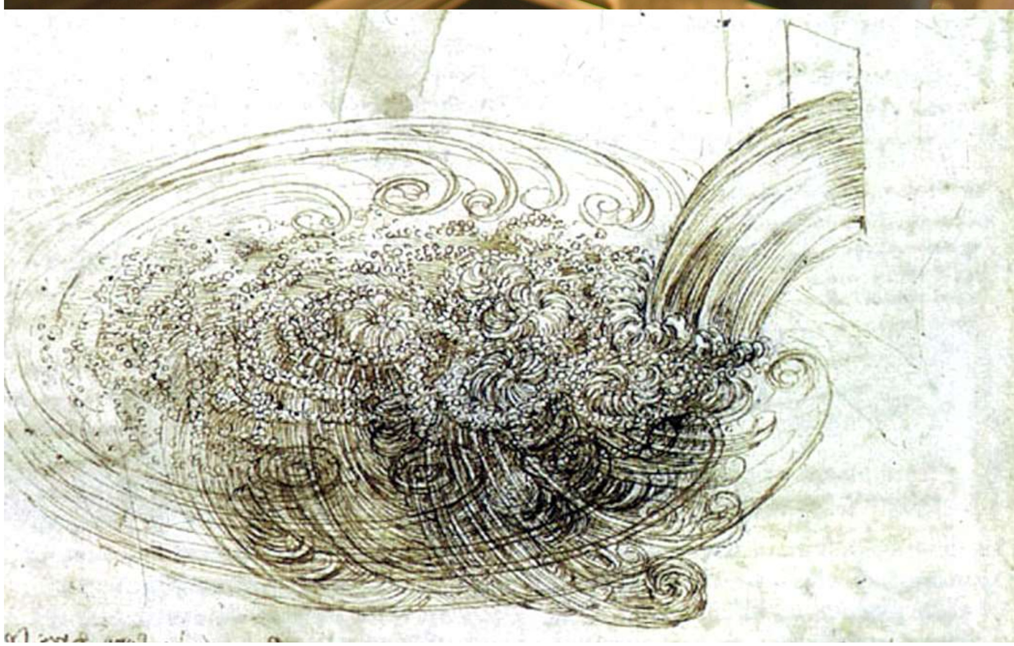
Medical data (CT, MR, DSA, PET, …)



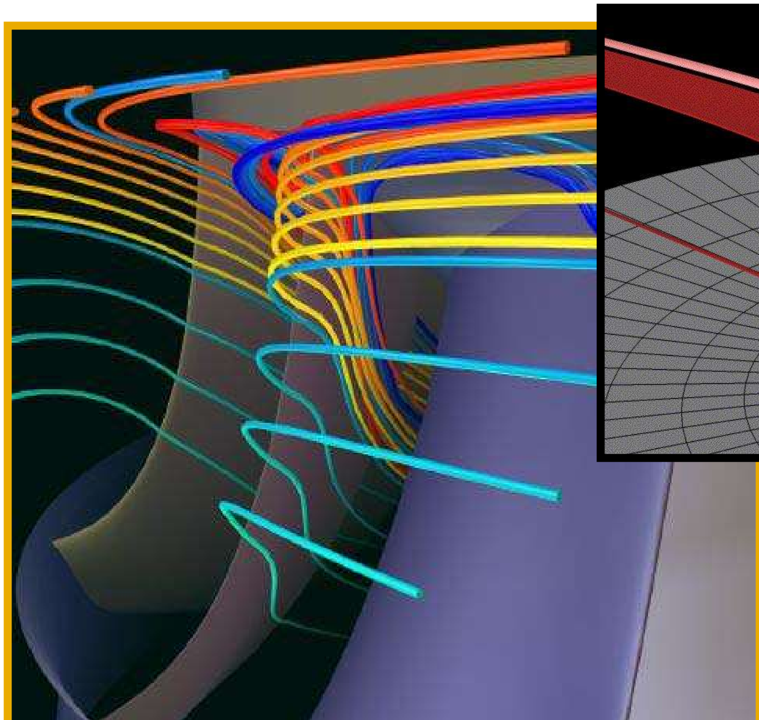
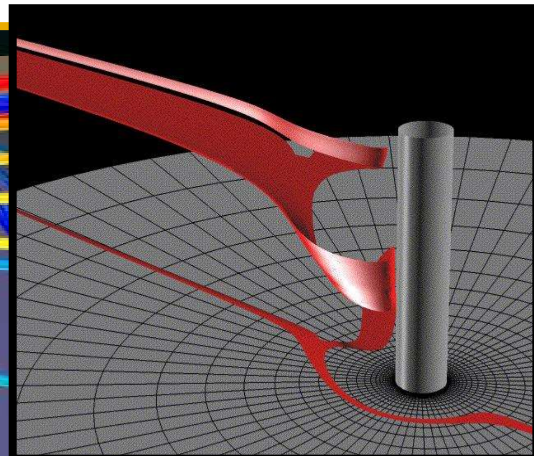


Scientific Visualization – Examples

Flow (vector field) data:
CFD, PIV, …



Scientific Visualization – Examples

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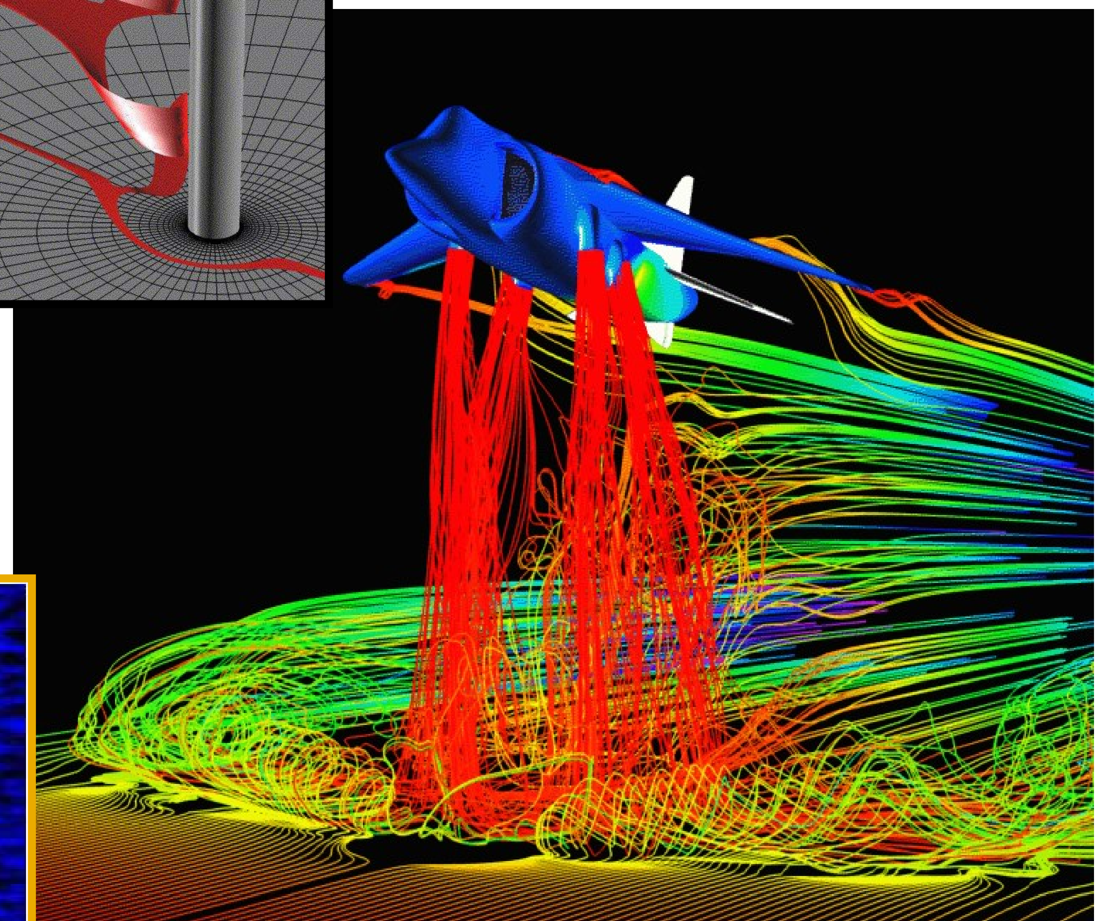
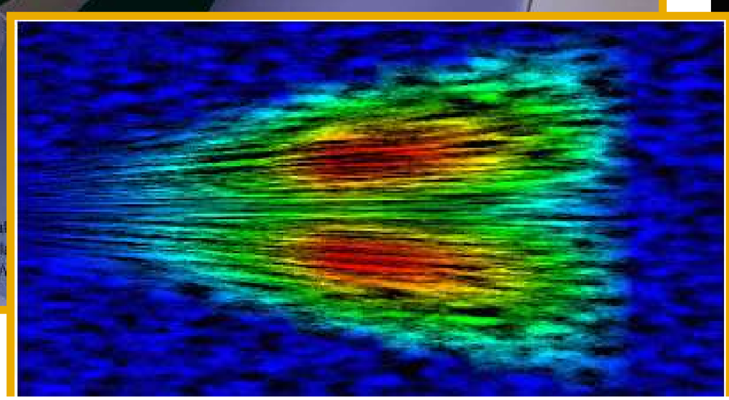
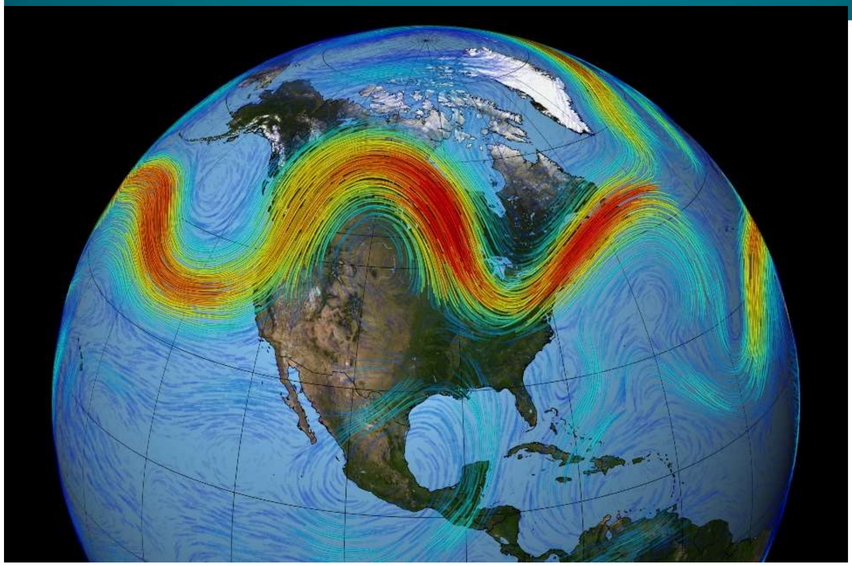
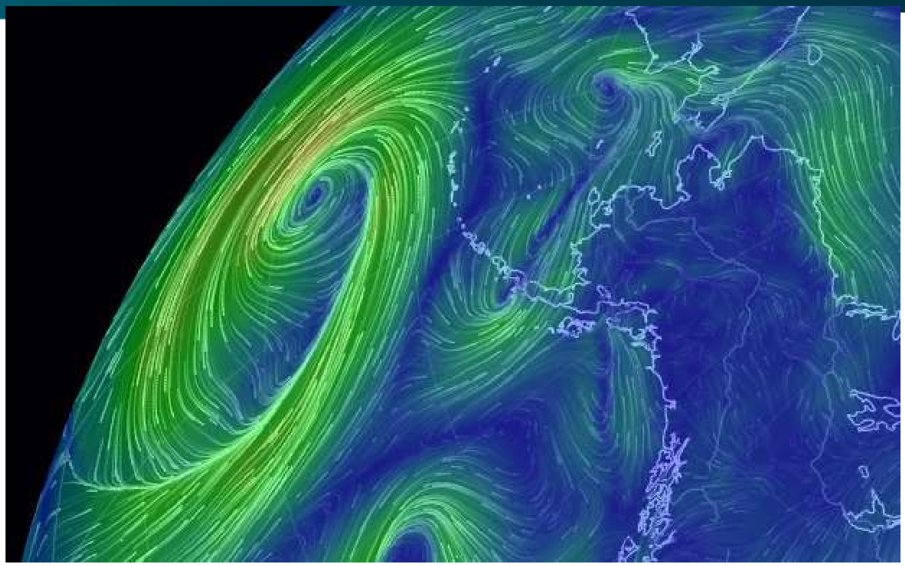
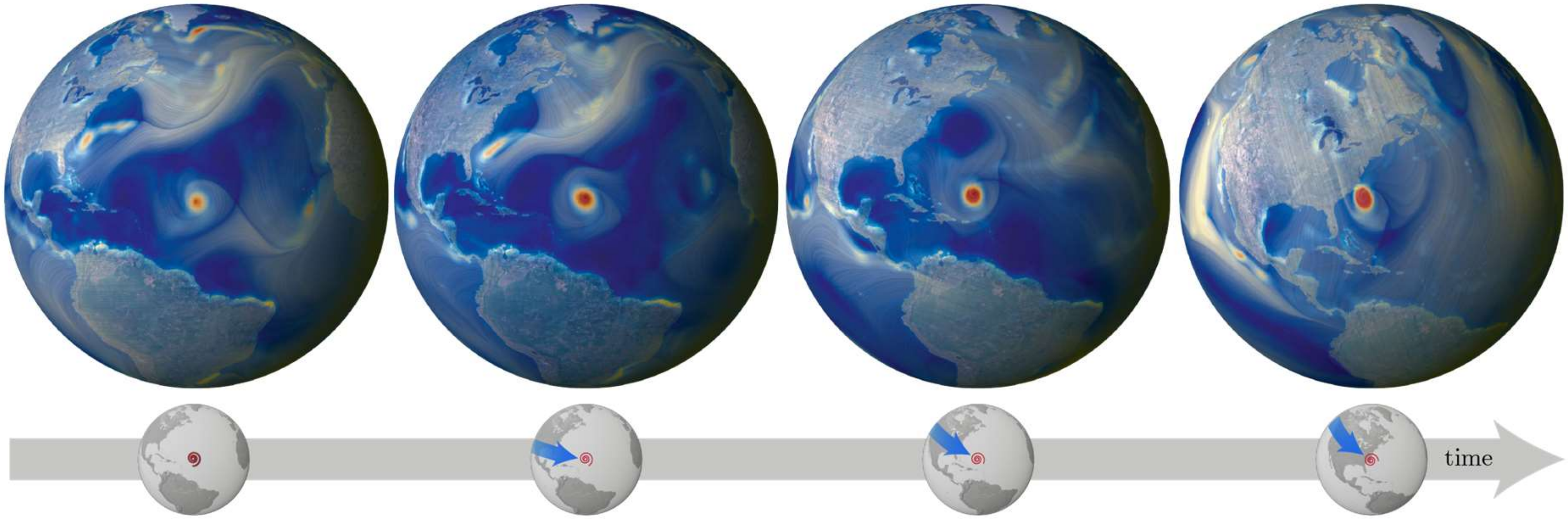



Scientific Visualization – Examples





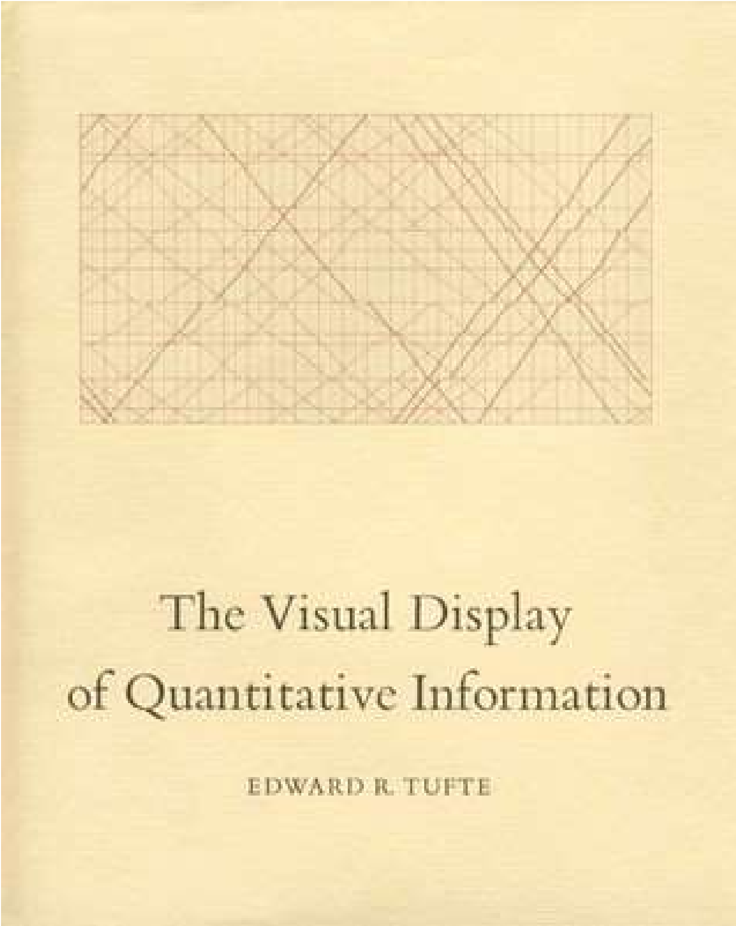


Data Graphics / Info Graphics / InfoVis

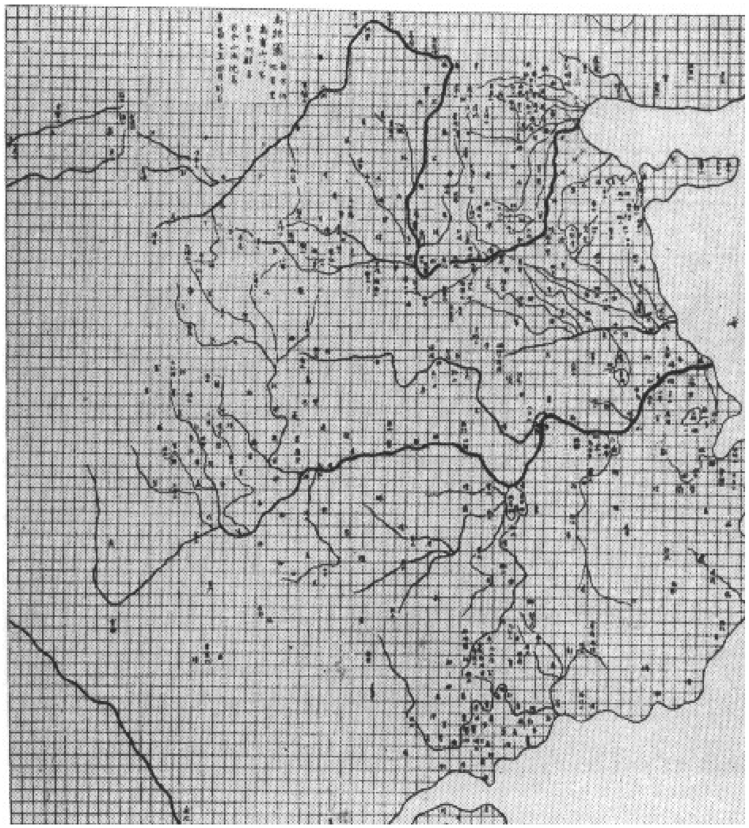
Famous book by Edward Tufte
(first edition 1983;
second edition 2001)

Selected great (and some bad) information visualizations

- William Playfair (1759-1823)
  – Bar chart, pie chart, …
- Charles Joseph Minard (1781-1870)
  – Napoleon’s Russia campaign, …
- …



Travelling Routes of Yu the Great

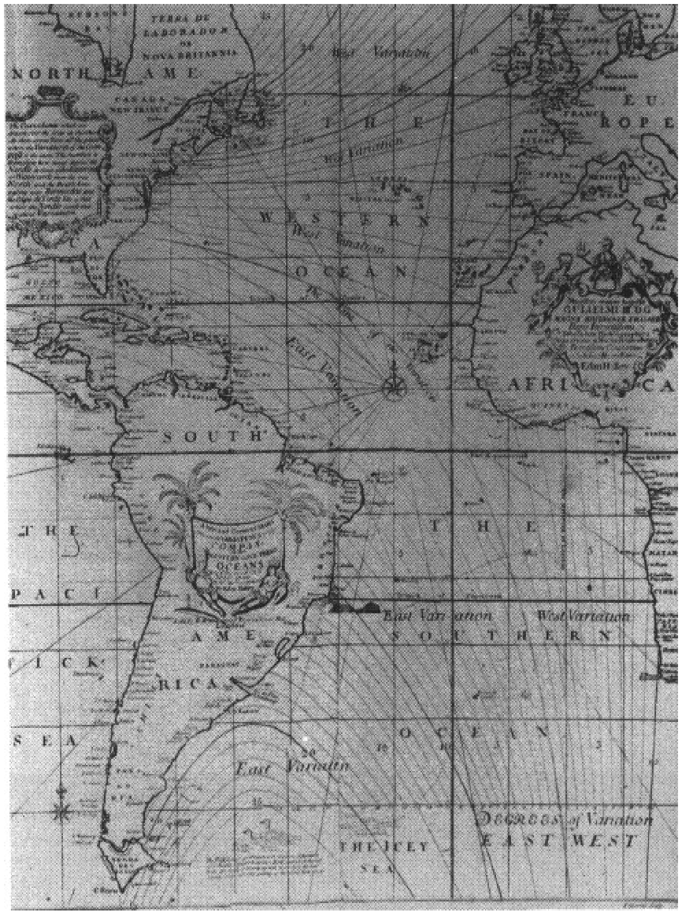


China, 1137

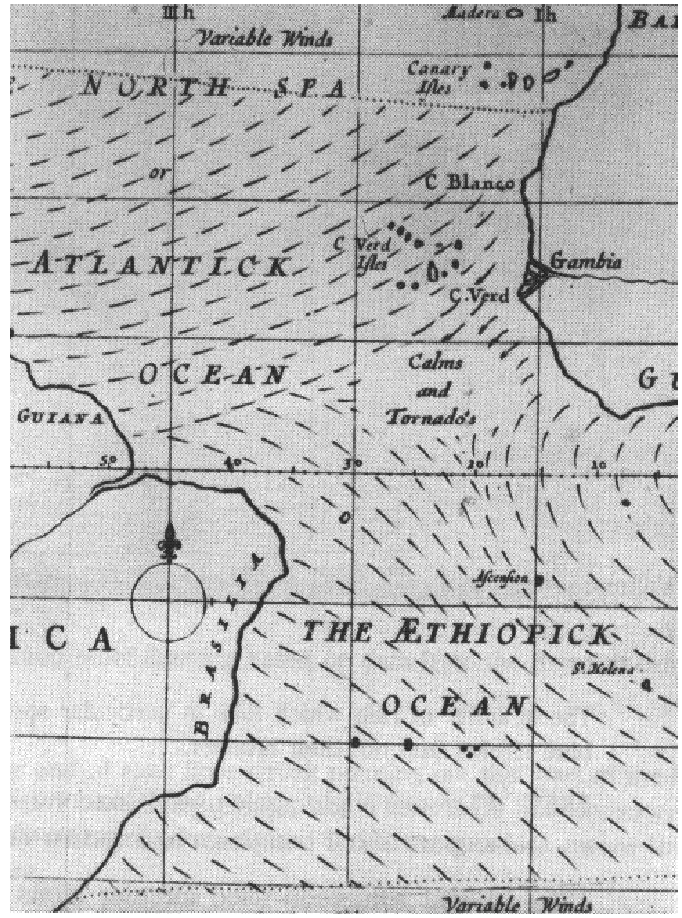
Geographical map using Cartesian coordinates

Grid with longitudinal and latitudinal lines

Cartography

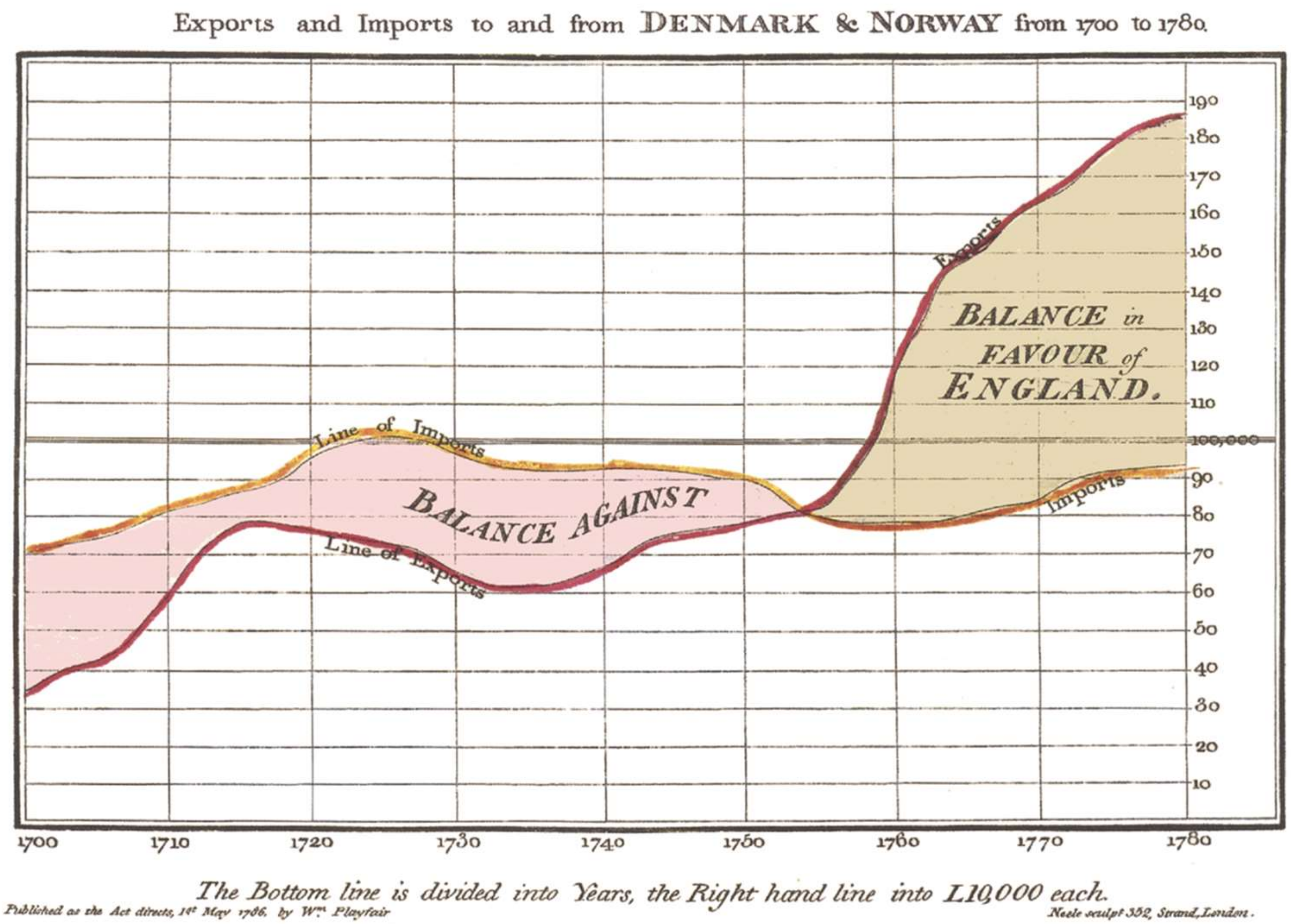


Isolines to visualize compass deviations



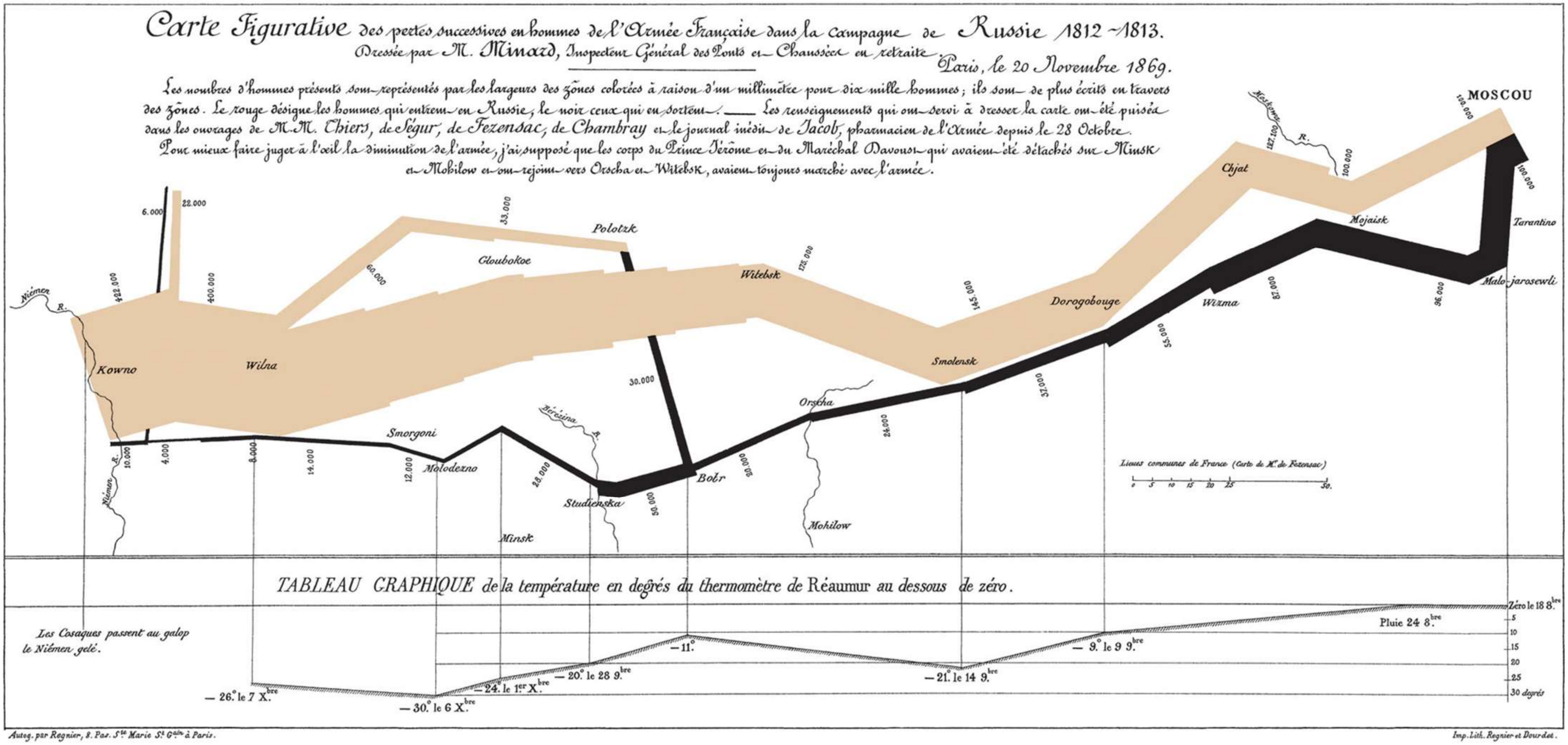
Wind flow visualization

Business Graphics



William Playfair, Scottish economist, Commercial and Political Atlas, 1785

Russia Military Campaign of Napoleon



Charles Joseph Minard, 1869

Cholera Epidemic in London

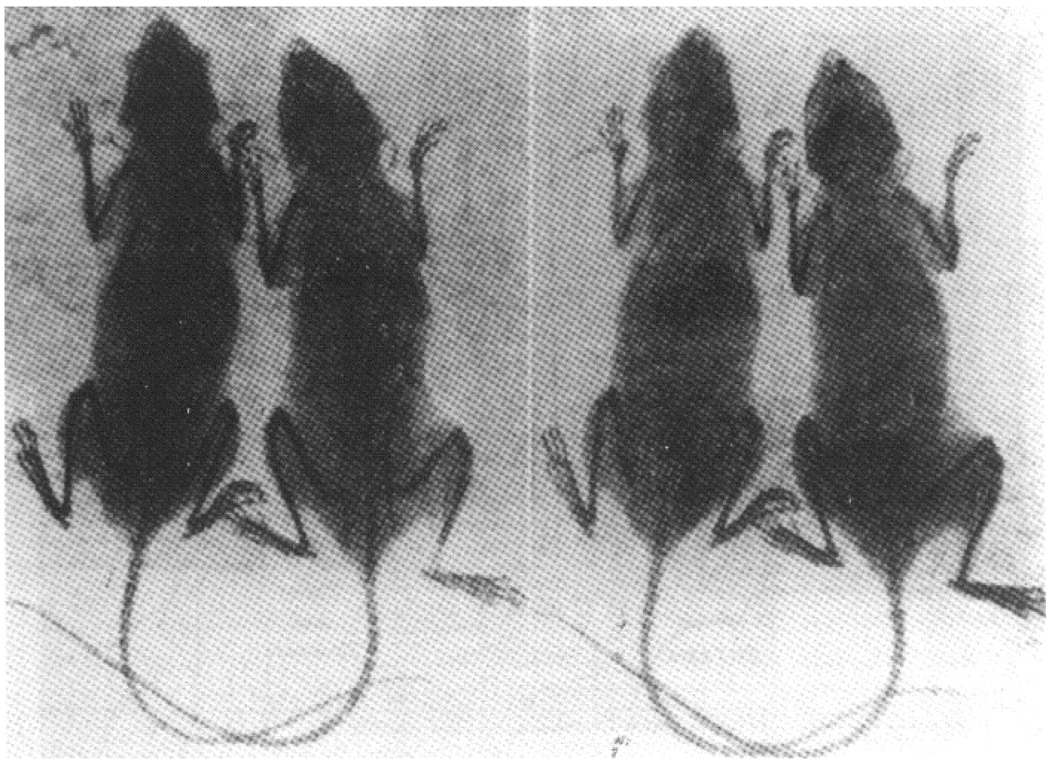
Dr. John Snow, 1854

Cartographic visualization

Correlation between water supply and disease incidents detected

Visualization in Medicine

- X-rays (Wilhelm Conrad Röntgen, 1895)
- Stereo X-ray images (1896)



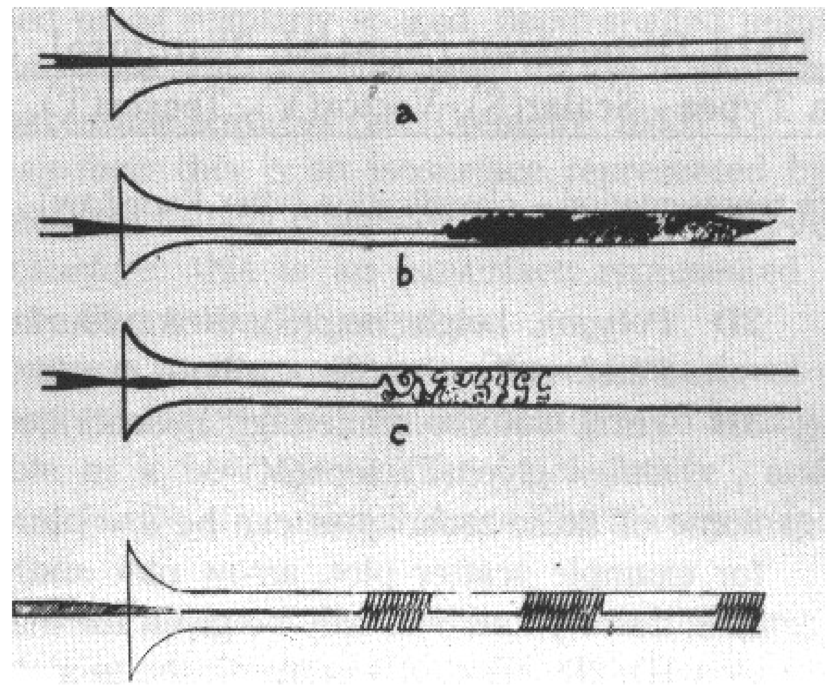
X-ray tomography

Experimental Flow Investigation

Fixation of tufts, ribbons on

- Aircraft in wind tunnels
- Ship hull in fluid tanks

- Introduction of smoke particles (in wind tunnel)
- Introduction of dye (in fluids)



Data Generation, Visualization, Interaction

Coupling varies considerably:

- Data generation (data acquisition):
  - Measuring, simulation, modeling
  - Can take very long (measuring, simulation)
  - Can be very costly (simulation, modeling)
- Visualization (rest of visualization pipeline):
  - Data enhancement, visualization mapping, rendering
  - Depending on computer, implementation: fast or slow
- Interaction (user feedback):
  - How can the user intervene, vary parameters

Passive Visualization

All three steps separated:

- Off-line data generation
  - Measurements
  - Simulation
  - Modeling
- Off-line Visualization
  - Previously generated data are visualized
  - Result: video or images/animation
- Passive Visualization
  - Viewing of the visualization results

Interactive Visualization

Only data generation is separated:

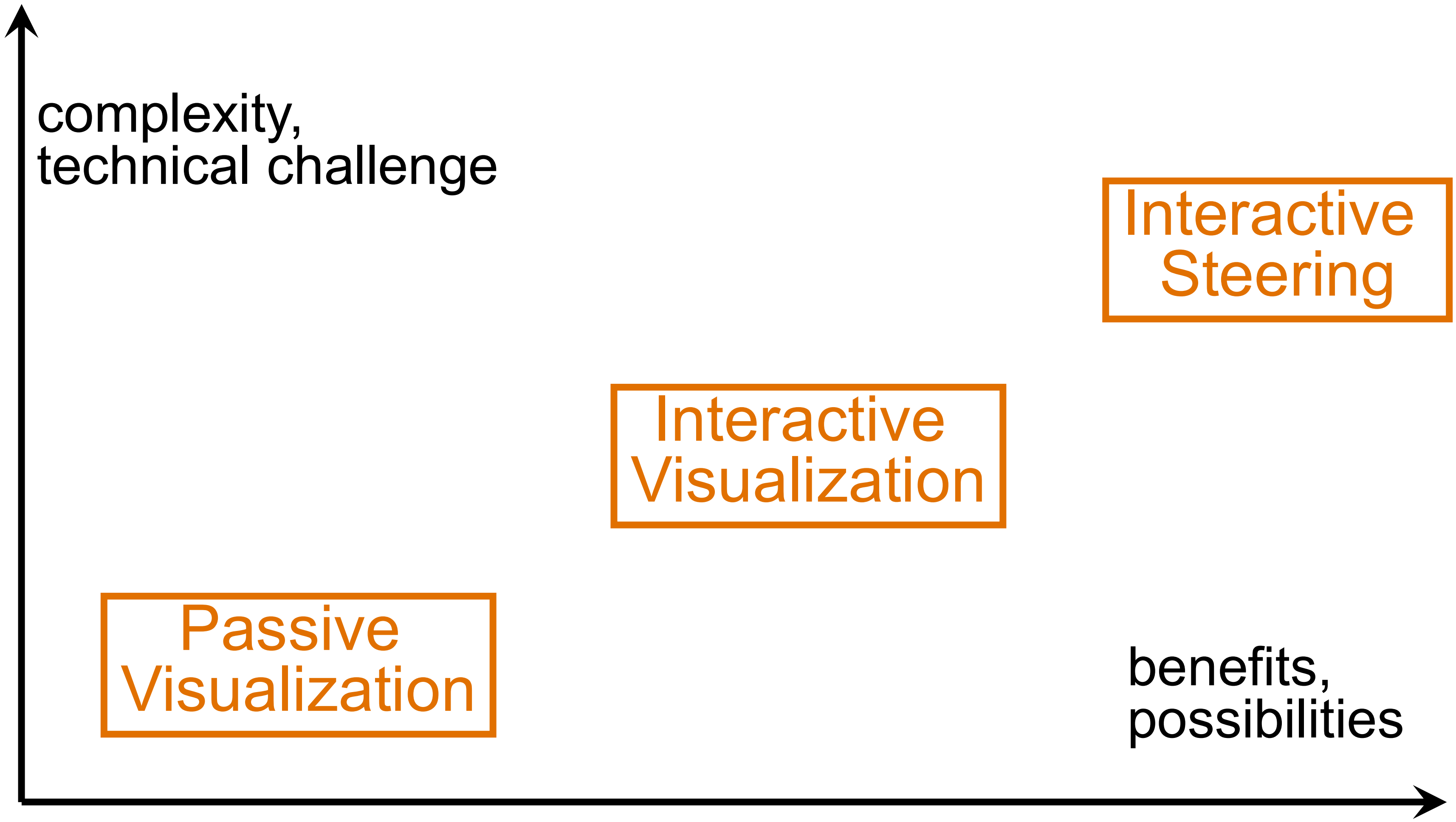
- Off-line data generation
  - Measurements, Simulation, Modeling
- Interactive visualization
  - Previously generated data are available
  - Visualization program allows interactive visualization of the data
  - Possibilities:
    choice, variation, parameterization of the visualization technique
  - Nowadays widespread
  - Focus of this course!

Interactive Steering

All three steps coupled:

- Interactive steering
  - Simulation and/or modelling (measuring) generate data “on the fly”
  - Interactive visualization allows “real-time” insight into the data
  - Extended possibilities:
    user can interfere with the simulation and/or the modeling, change the design, ...
  - Often requires lots of effort, very costly

Visualization Scenarios



Thank you.

Thanks for material

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