

# **CS 247 – Scientific Visualization**

## **Lecture 2: Introduction, Pt. 2**

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# Reading Assignment #1 (until Jan 31)



**Sign up for piazza!**

**<http://piazza.com/kaust.edu.sa/spring2022/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 !

# 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



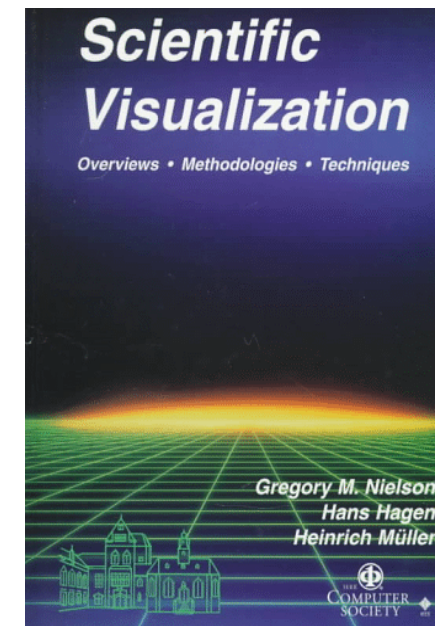
# Visualization – Background



Leonardo da Vinci (1452-1519)

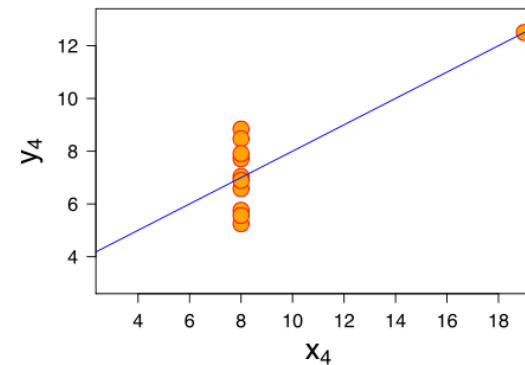
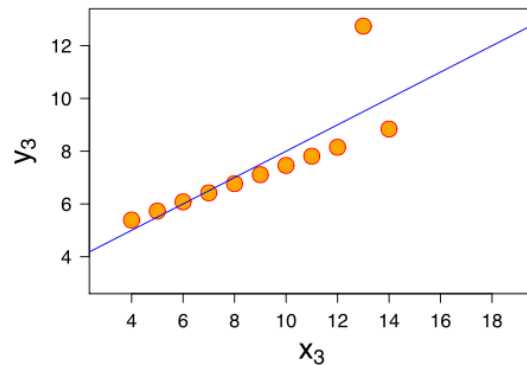
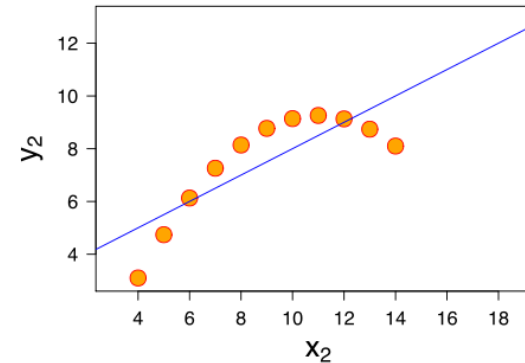
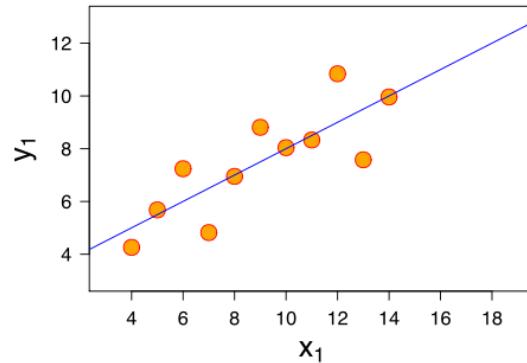


- Visualization in general: quite old
- Often an intuitive step: graphical illustration
- Data with ever increasing sizes  $\Rightarrow$  graphical approach necessary
- Simple approaches known from business graphics (Grapher, Excel, etc.)
- Visualization: scientific discipline since ~1987
- First dedicated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



1997 9

# Example: Anscombe's Quartet



Francis Anscombe, 1973

[https://en.wikipedia.org/wiki/Anscombe%27s\\_quartet](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

- Volume Visualization
- Flow Visualization



## Scientific Visualization

Inherent spatial reference

3D

- 
- Information Visualization
  - Visual Analytics

nD

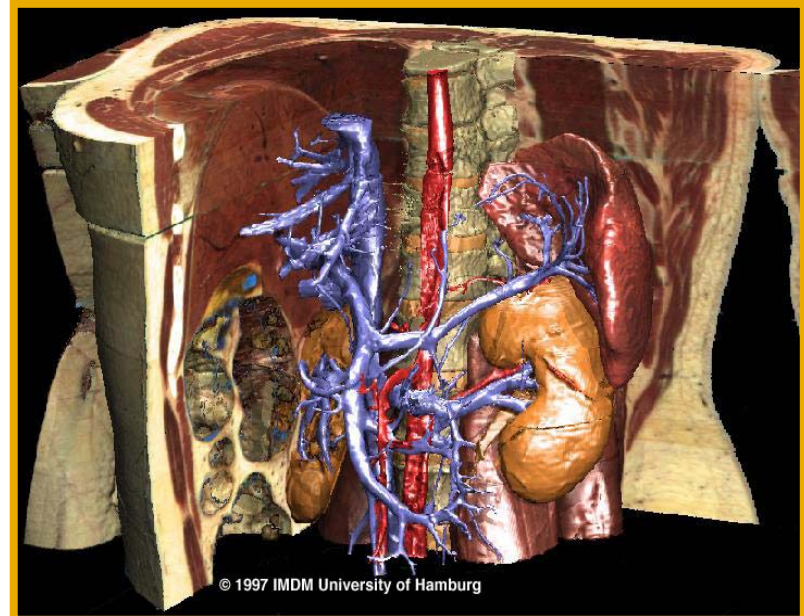
Usually no spatial reference

But these lines are becoming more and more blurred!

# Scientific Visualization – Examples



Medical data (CT, MR, DSA, PET, ...)



© 1997 IMDM University of Hamburg



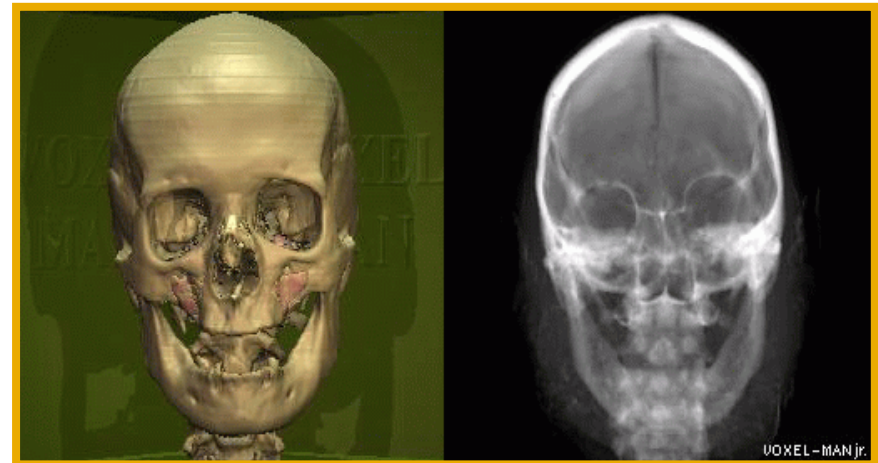
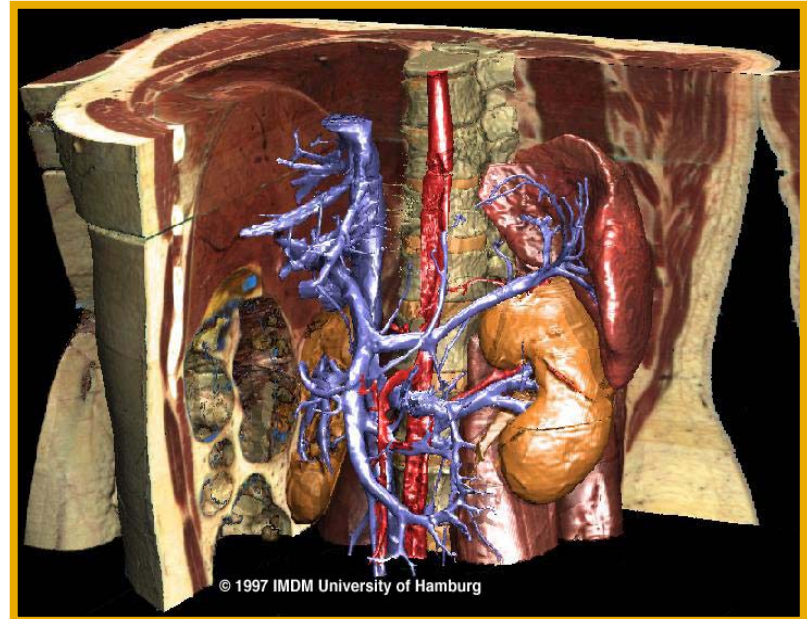
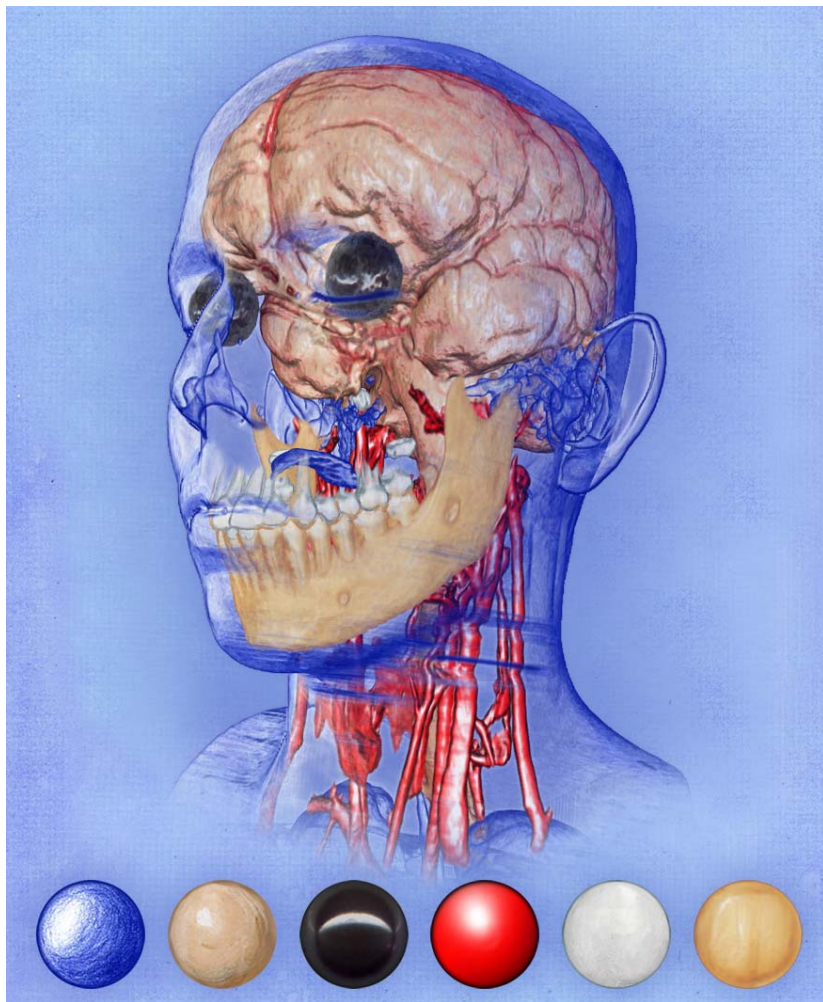
VOXEL-MAN jr.



# Scientific Visualization – Examples



Medical data (CT, MR, DSA, PET, ...)





# Scientific Visualization – Examples



Flow (vector field) data:  
CFD, PIV, ...

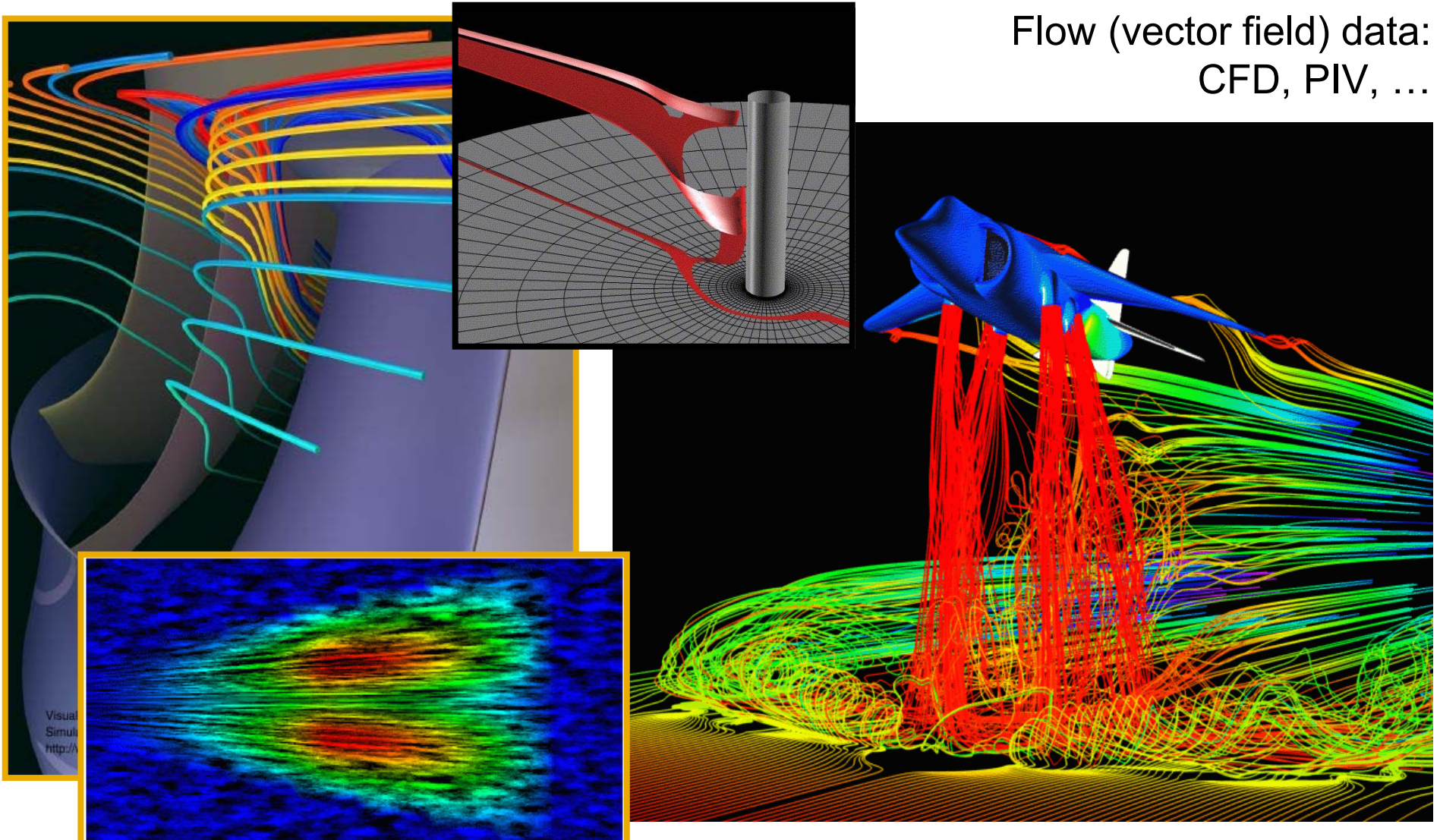




# Scientific Visualization – Examples

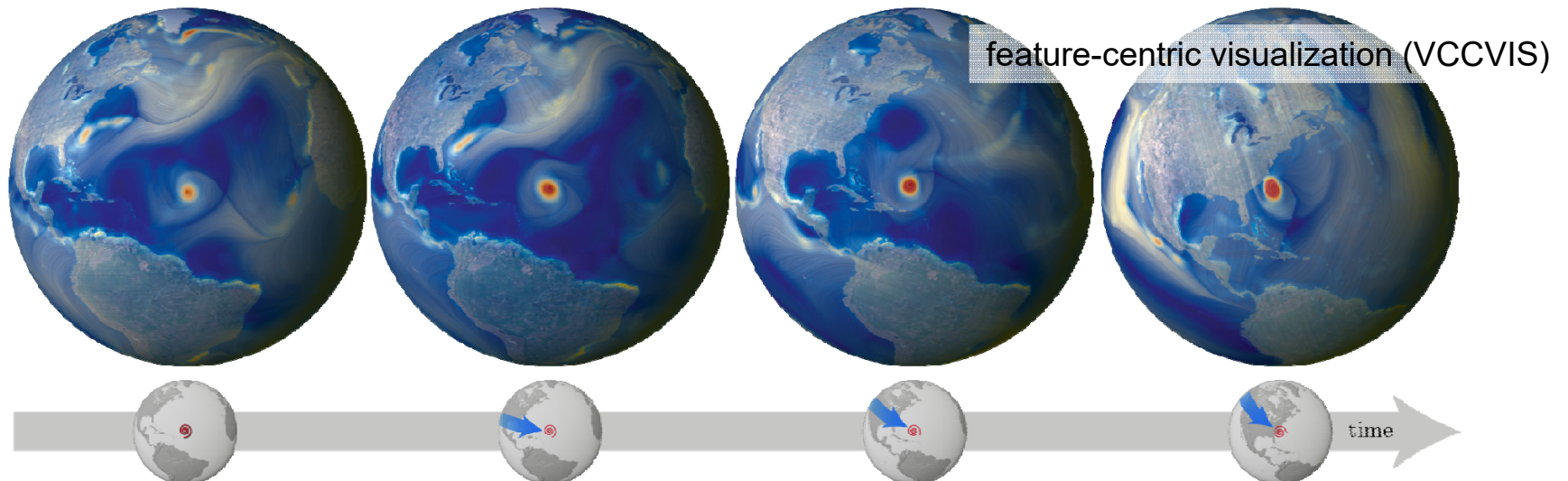
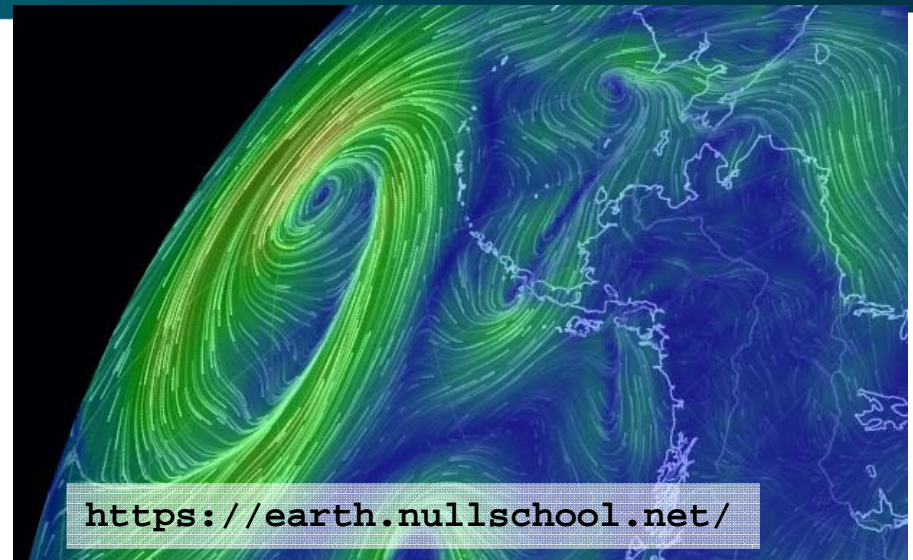
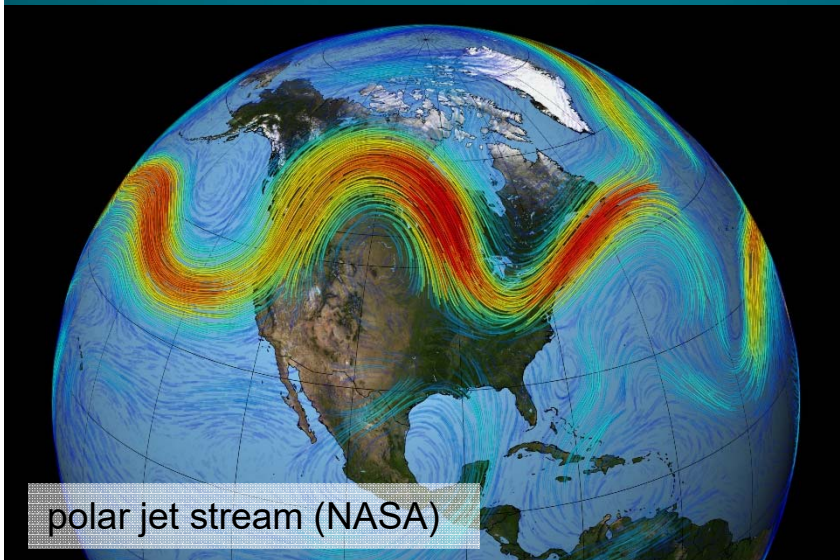


Flow (vector field) data:  
CFD, PIV, ...





# Scientific Visualization – Examples



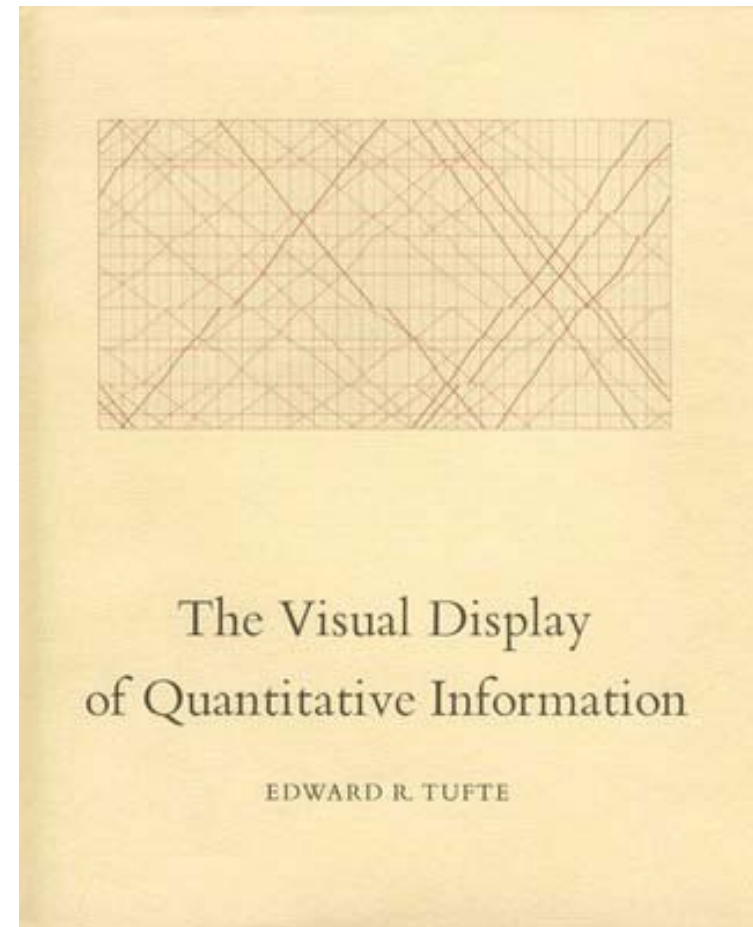
# Data Graphics / Info Graphics / InfoVis



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

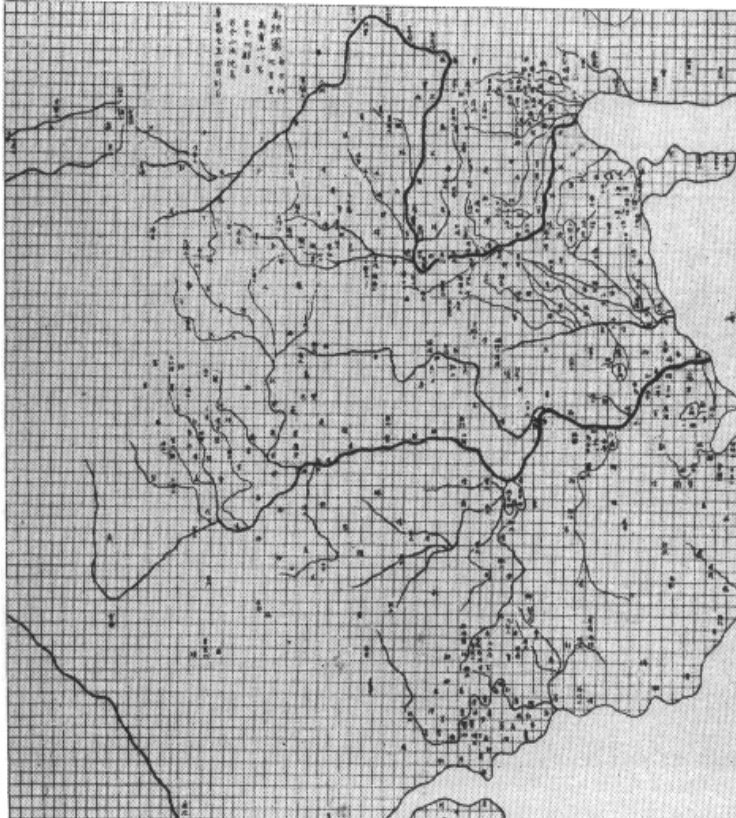
Selected great (and some bad)  
information visualizations

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





# Travelling Routes of Yu the Great

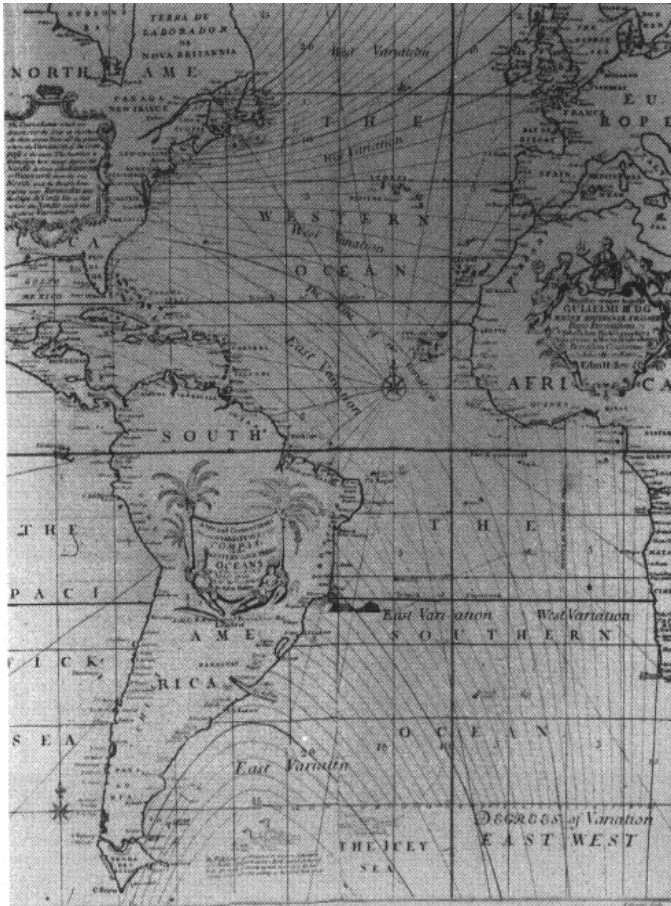


China, 1137

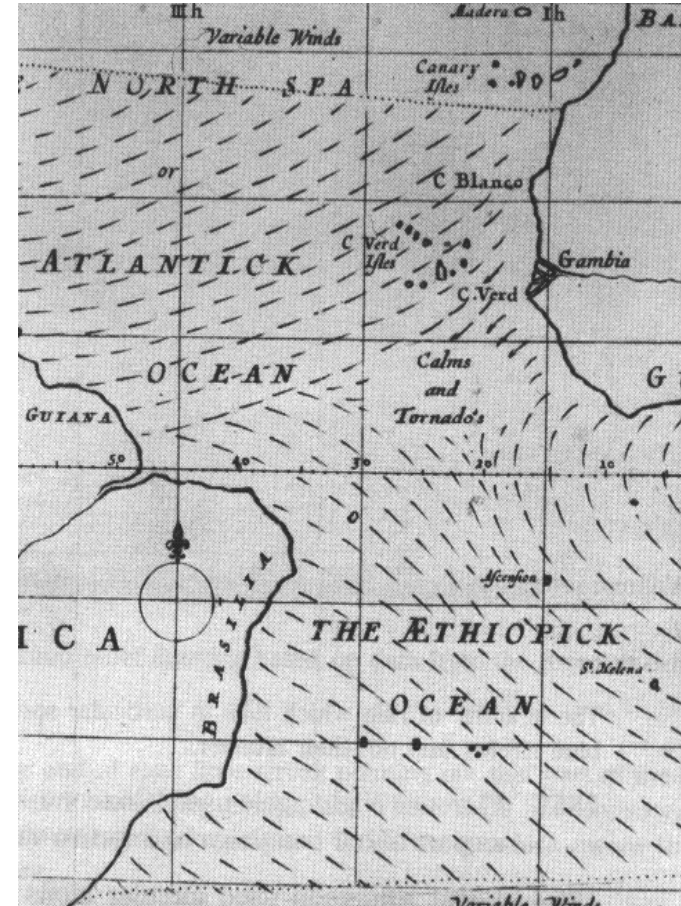
Geographical map using Cartesian coordinates

Grid with longitudinal and latitudinal lines

# Cartography



Isolines to visualize compass deviations



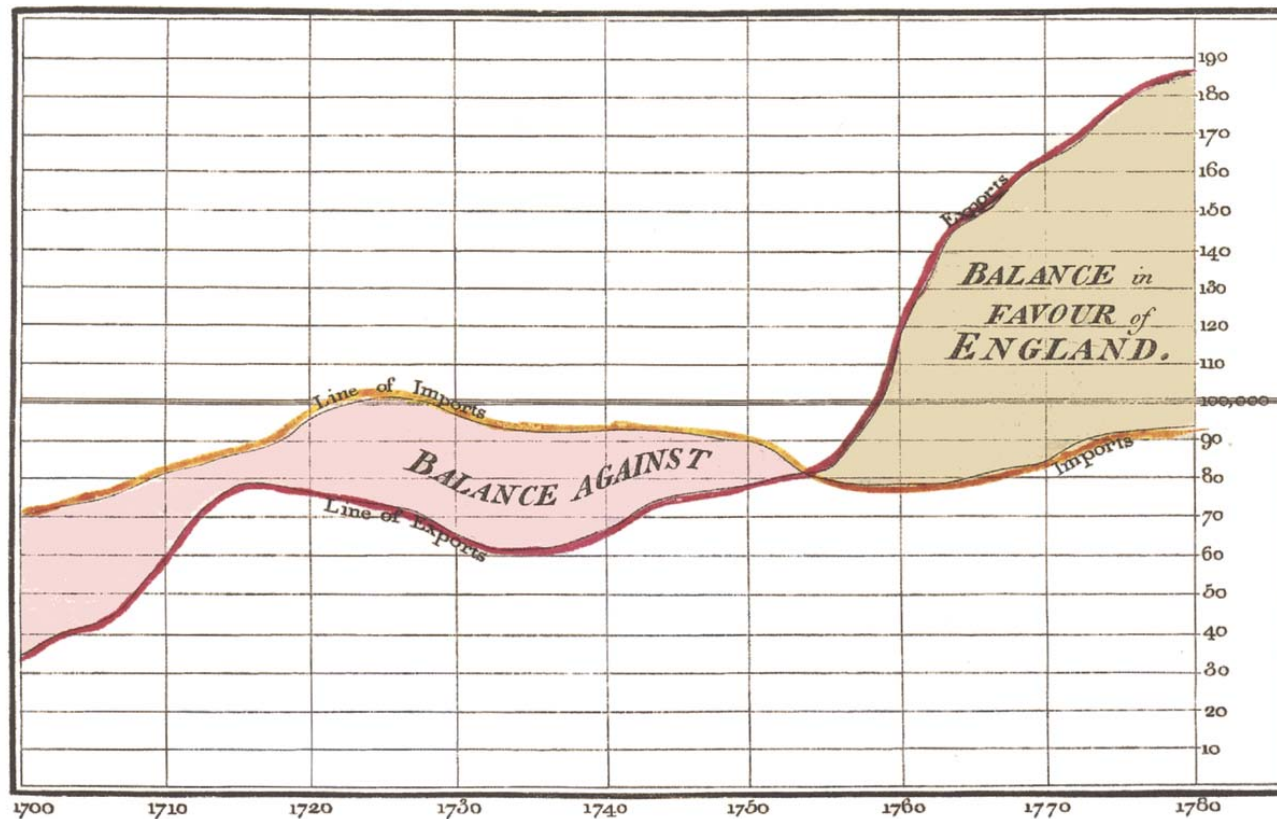
Wind flow visualization



# Business Graphics



Exports and Imports to and from DENMARK & NORWAY from 1700 to 1780.



*The Bottom line is divided into Years, the Right hand line into £10,000 each.*  
*Published as the Act direct, 1<sup>st</sup> May 1786, by W<sup>m</sup> Playfair* *Keble sculp<sup>t</sup> 302, Strand, London.*

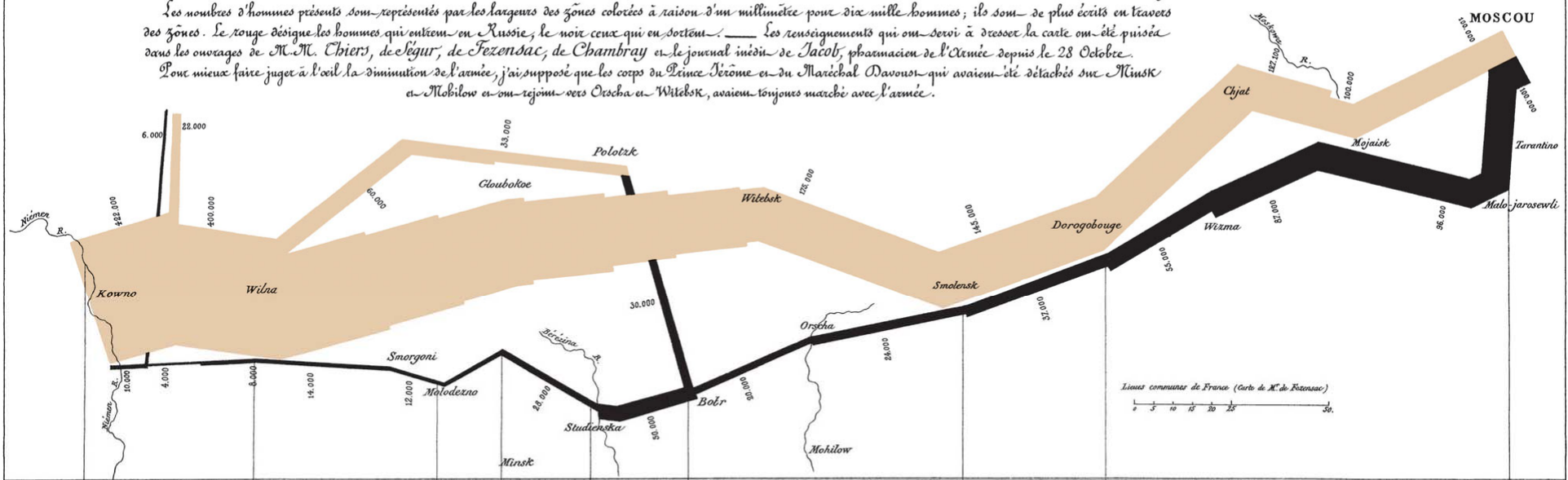
William Playfair, Scottish economist, Commercial and Political Atlas, 1785

# Russia Military Campaign of Napoleon

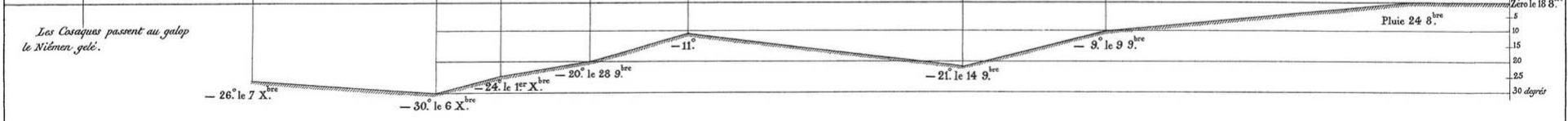


*Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.*  
 Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largeurs des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zones. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M. M. Chiers, de Légar, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre. Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davout qui avaient été détachés sur Minsk et Mohilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.



*TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.*



*Autog. par Ragnier, 8. Par. S<sup>te</sup> Marie S<sup>te</sup> G<sup>de</sup> à Paris.*

*Imp. Lit. Ragnier et Douvdat.*

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

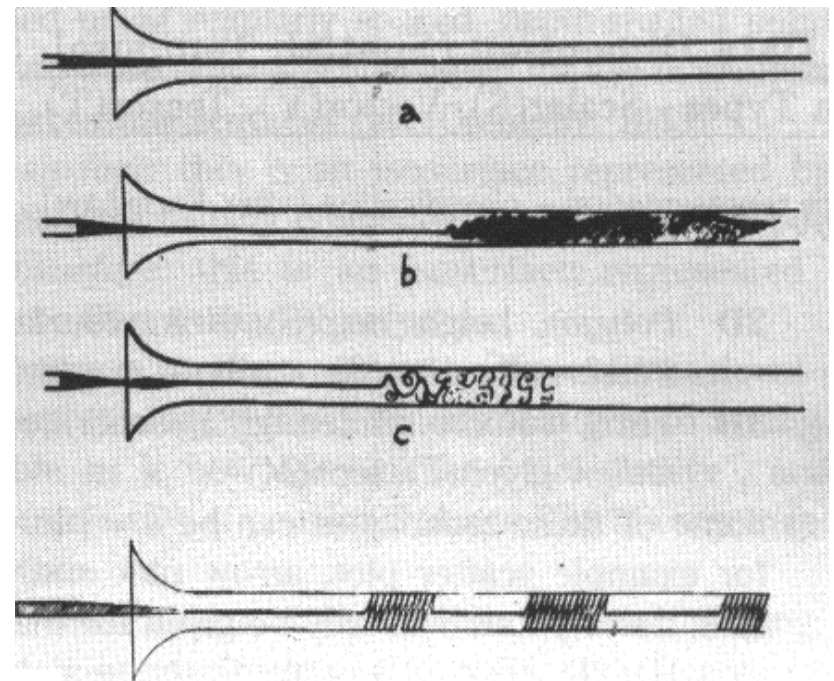


# Experimental Flow Investigation



## 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

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- Off-line Visualization

- Previously generated data are visualized
- Result: video or images/animation

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- Passive Visualization

- Viewing of the visualization results



# Interactive Visualization



Only data generation is separated:

- Off-line data generation

- Measurements, Simulation, Modeling

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- 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



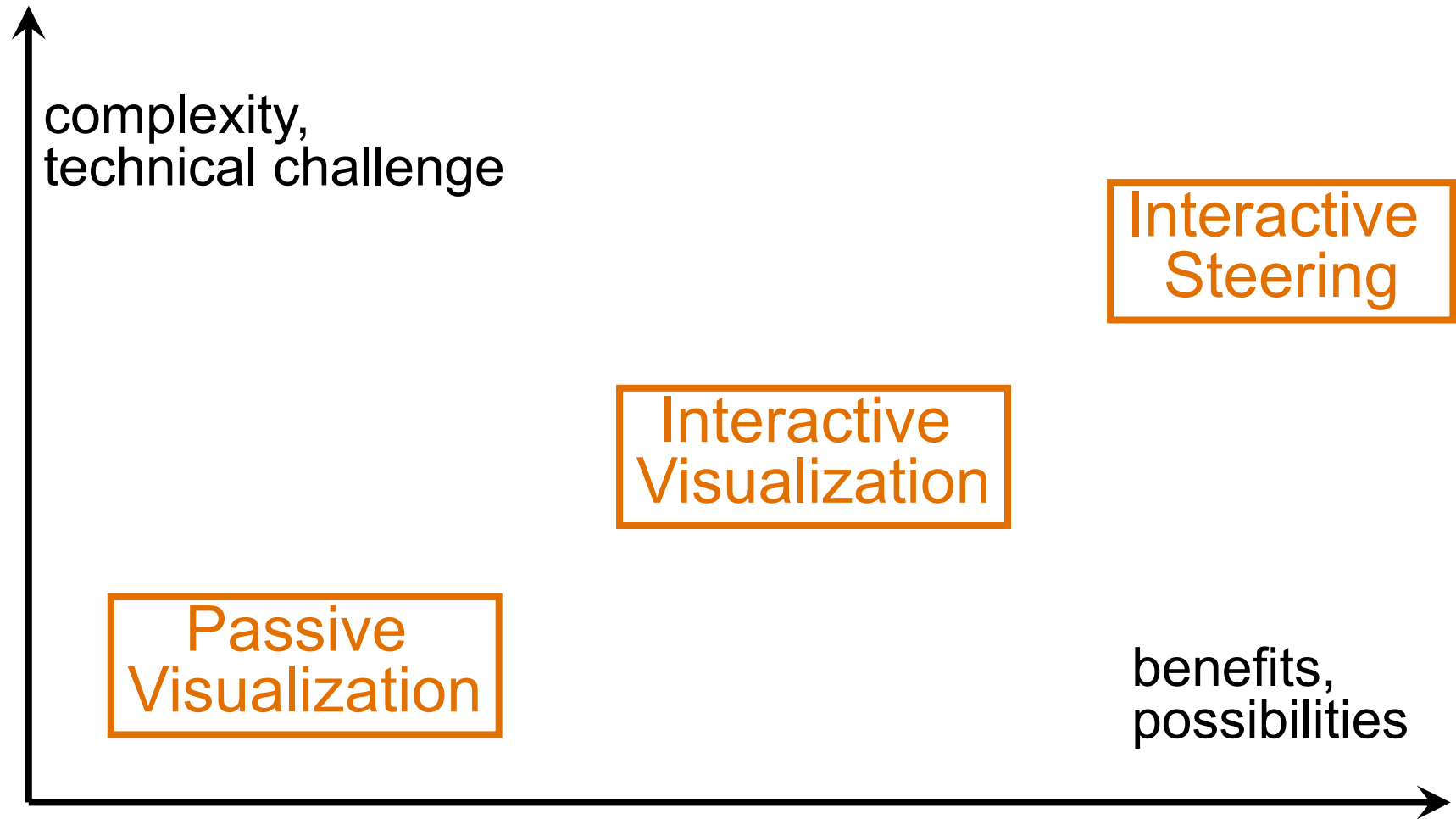
All three steps coupled:

- **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

- Helwig Hauser
- Eduard Gröller
- Daniel Weiskopf
- Torsten Möller
- Ronny Peikert
- Philipp Muigg
- Christof Rezk-Salama