
# CS 247 – Scientific Visualization
# Lecture 3: The Visualization Pipeline

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# Reading Assignment #2 (until Feb 5)

Read (required):

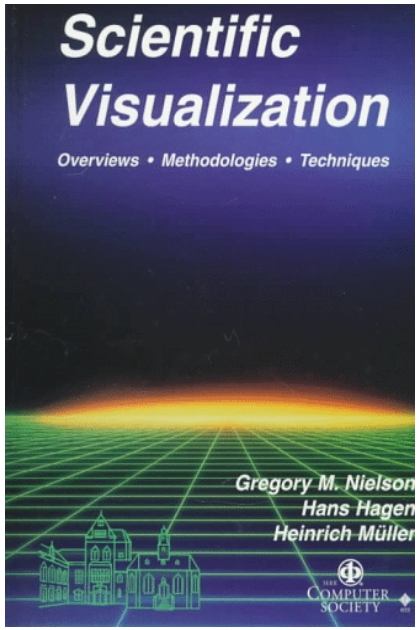
- Data Visualization book, finish Chapter 2
- Data Visualization book, Chapter 3 until 3.5 (inclusive)
- Data Visualization book, Chapter 4 until 4.1 (inclusive)

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

# Visualization – Background

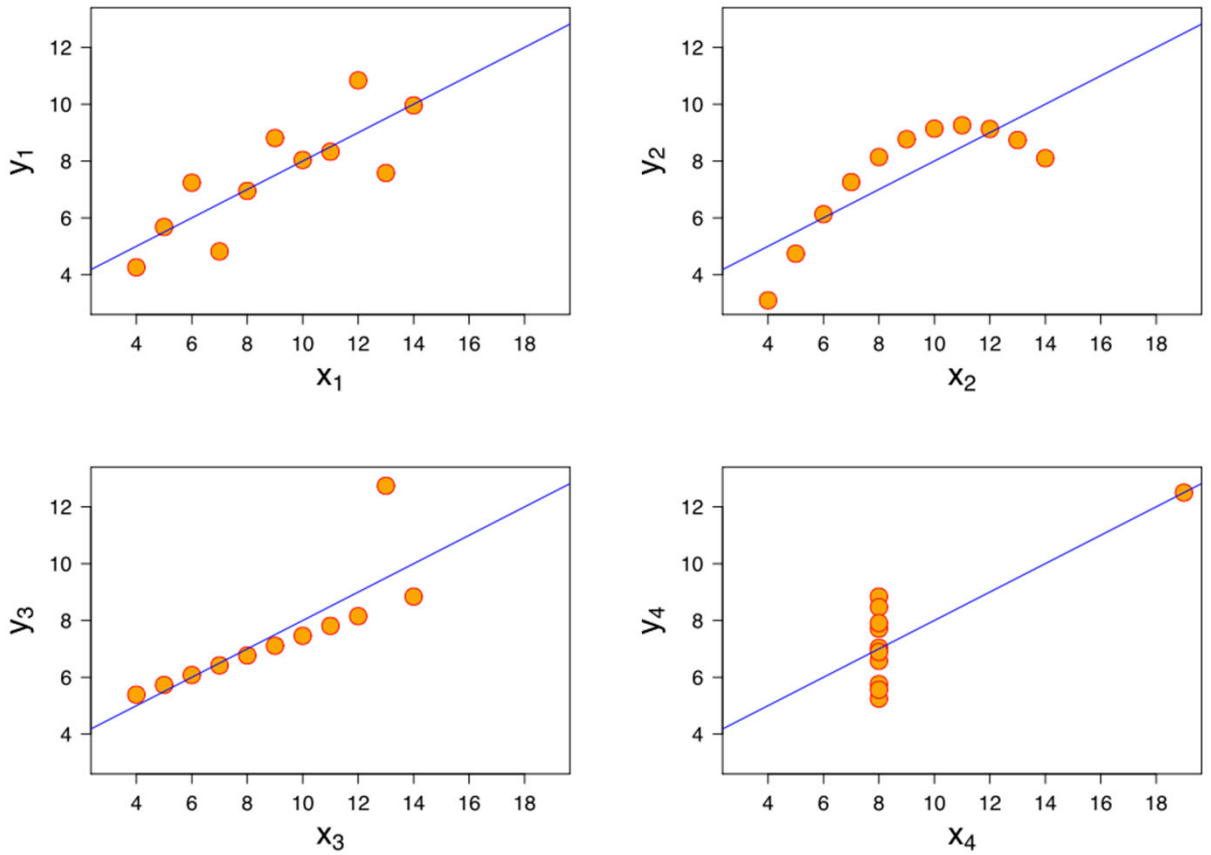
Leonardo da Vinci (1452-1519)

- 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 → 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 – Three Major Areas

Four major areas

- Volume Visualization
- Flow Visualization

Scientific Visualization

Inherent spatial reference

3D

nD

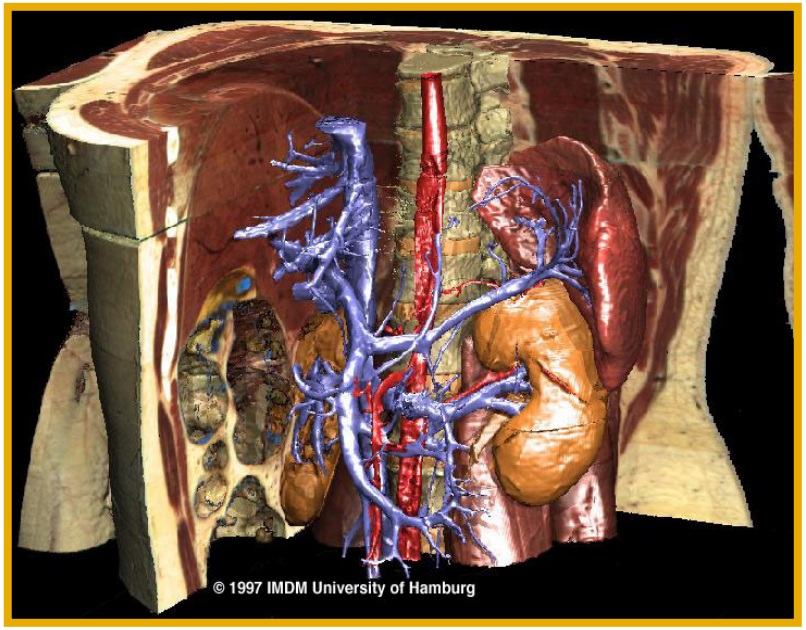
- Information Visualization
- Visual Analytics

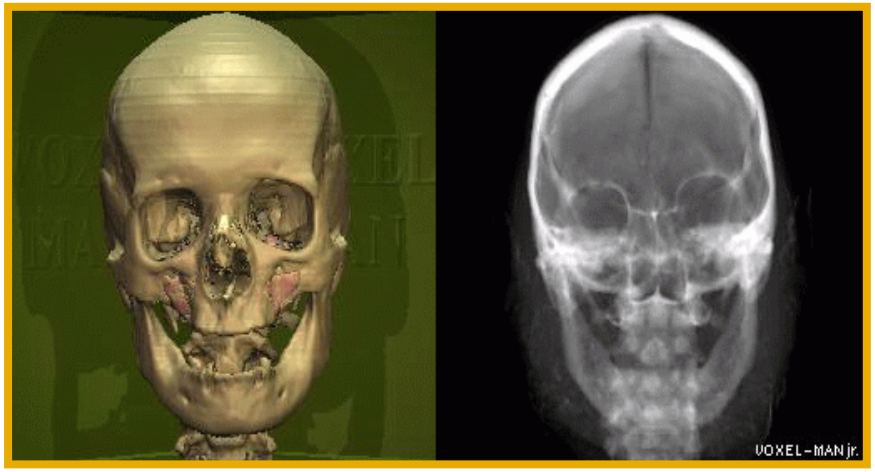
Usually no spatial reference

But these lines are becoming more and more blurred!

# Scientific Visualization – Examples

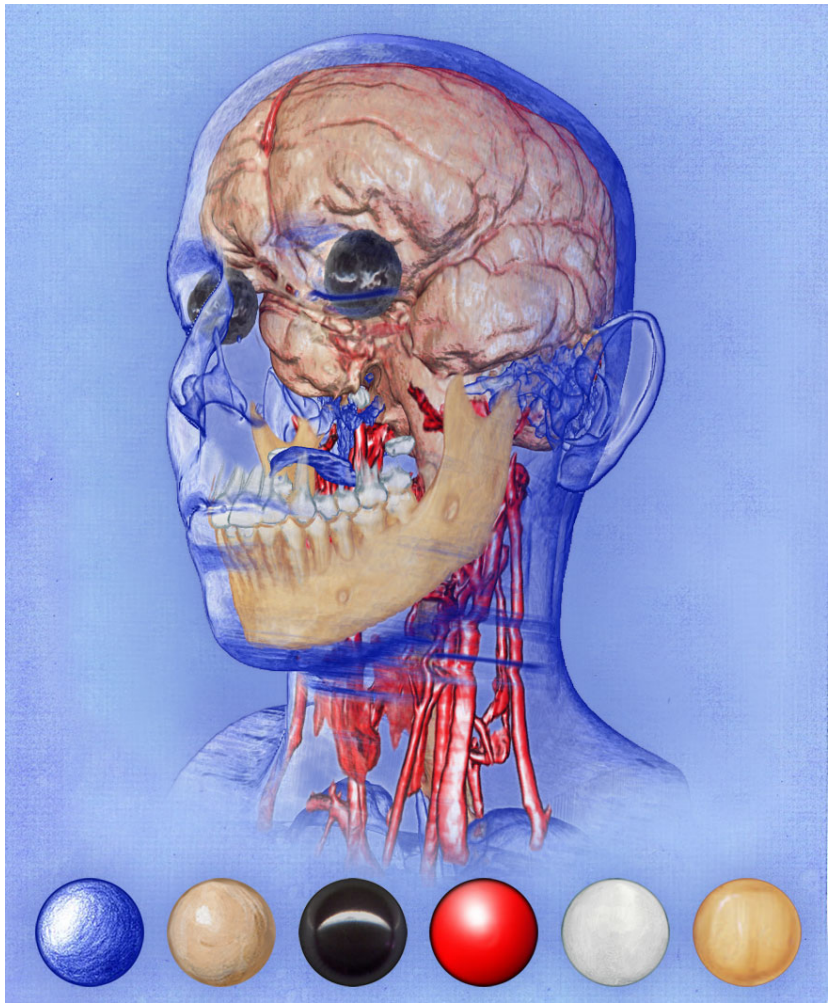
Medical data (CT, MR, DSA, PET, …)

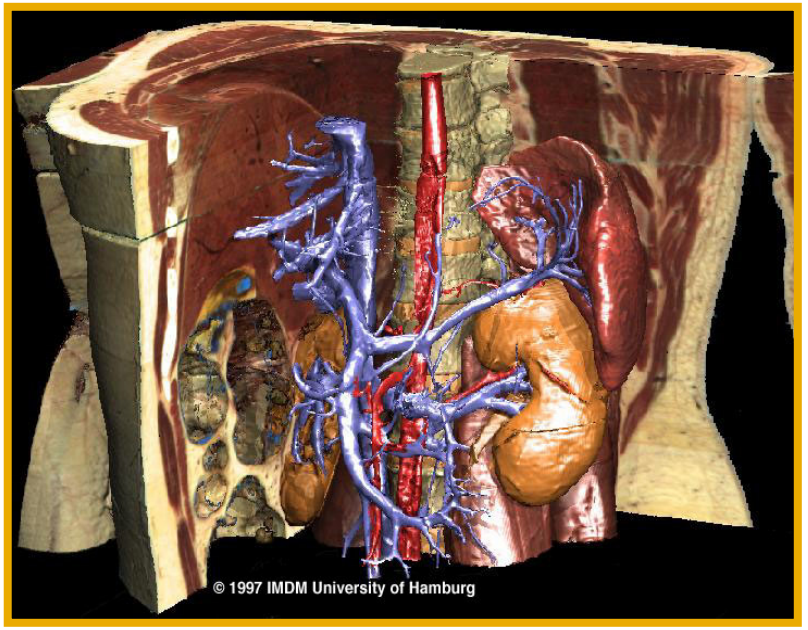


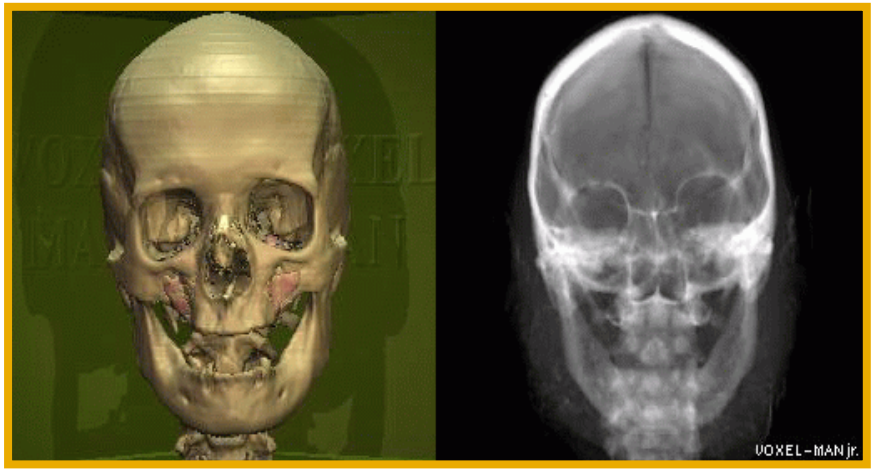



# Scientific Visualization – Examples

Medical data (CT, MR, DSA, PET, …)

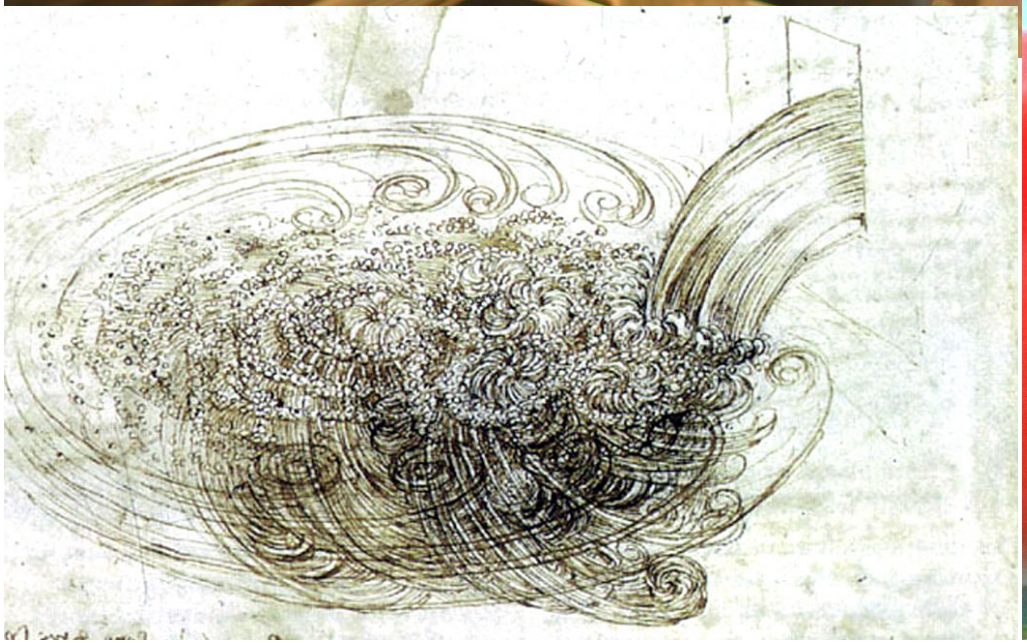




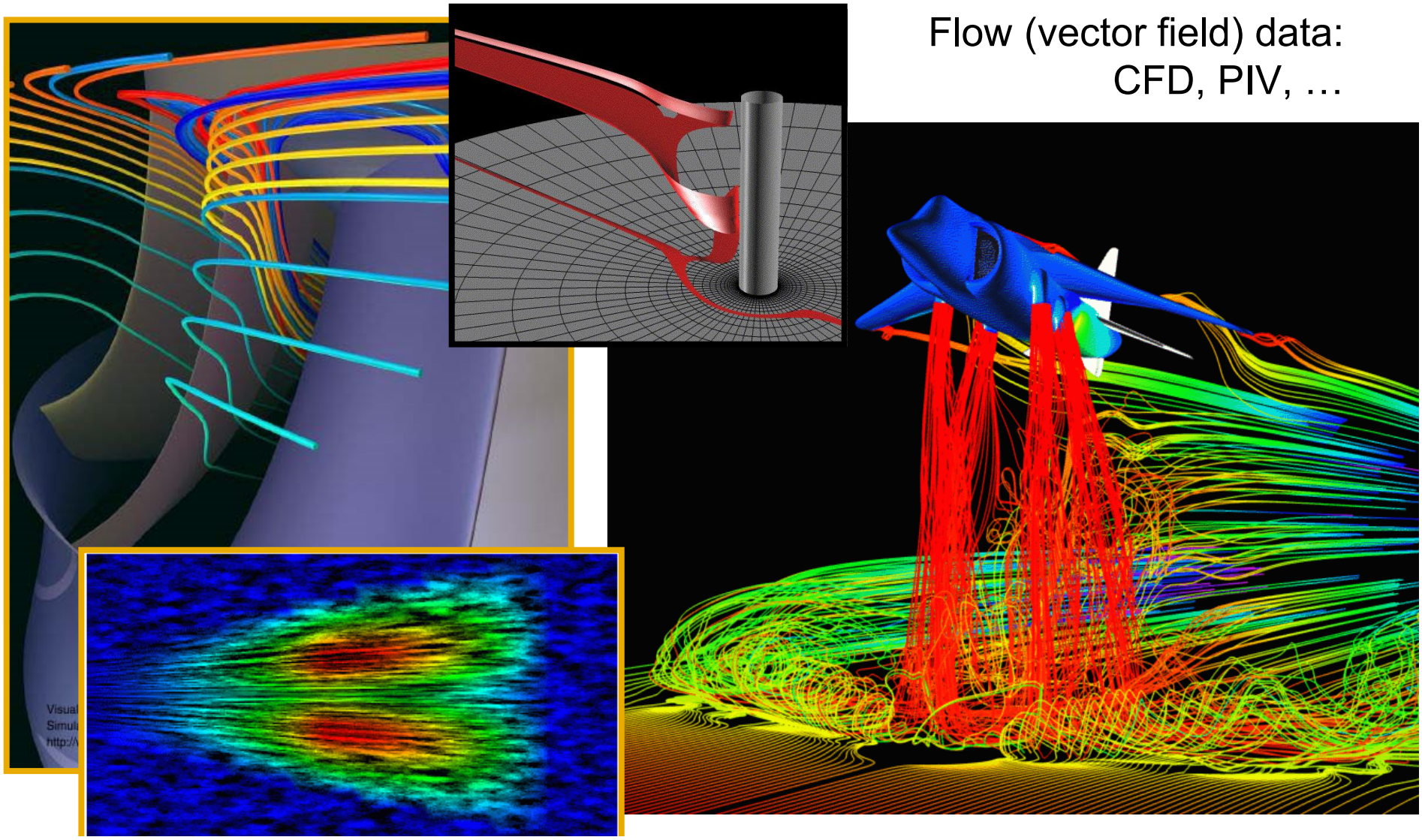



# Scientific Visualization – Examples

Flow (vector field) data:
CFD, PIV, …

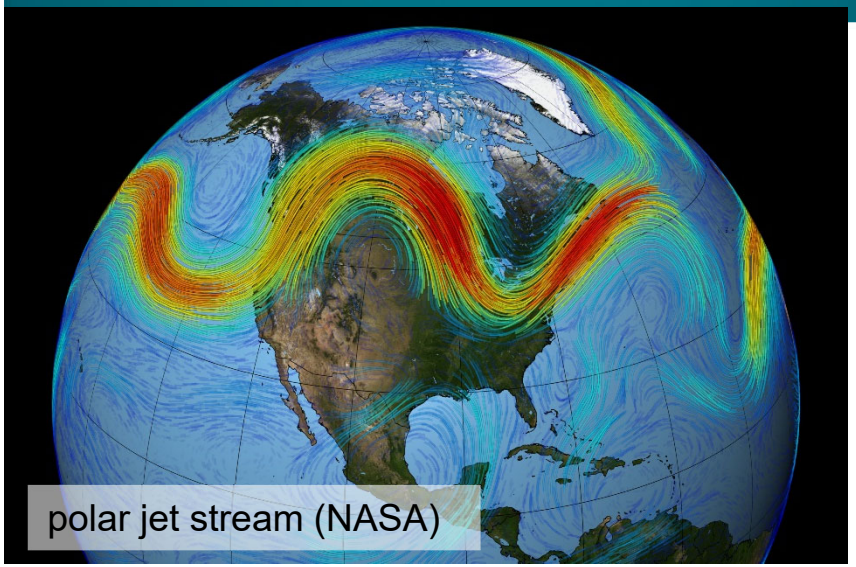


# Scientific Visualization – Examples

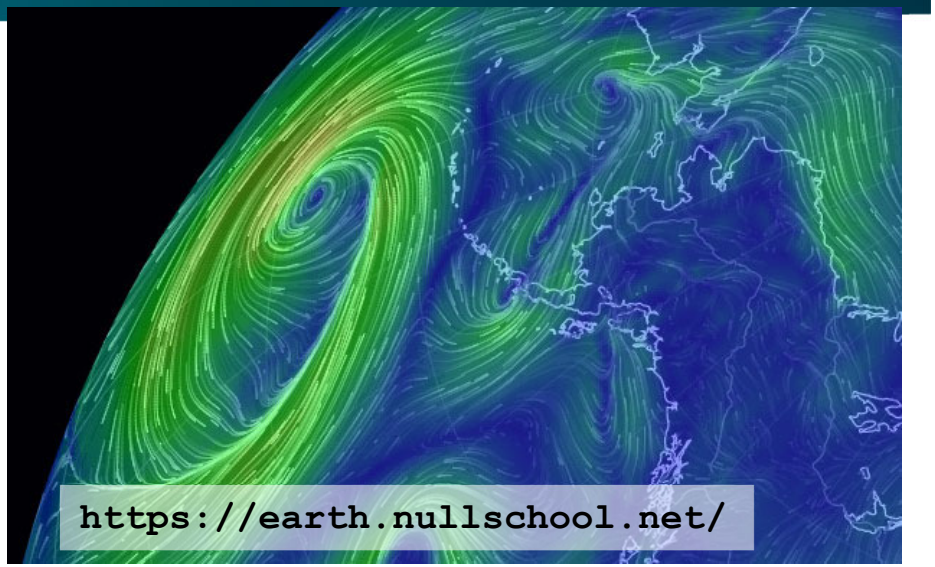


Flow (vector field) data:
CFD, PIV, …

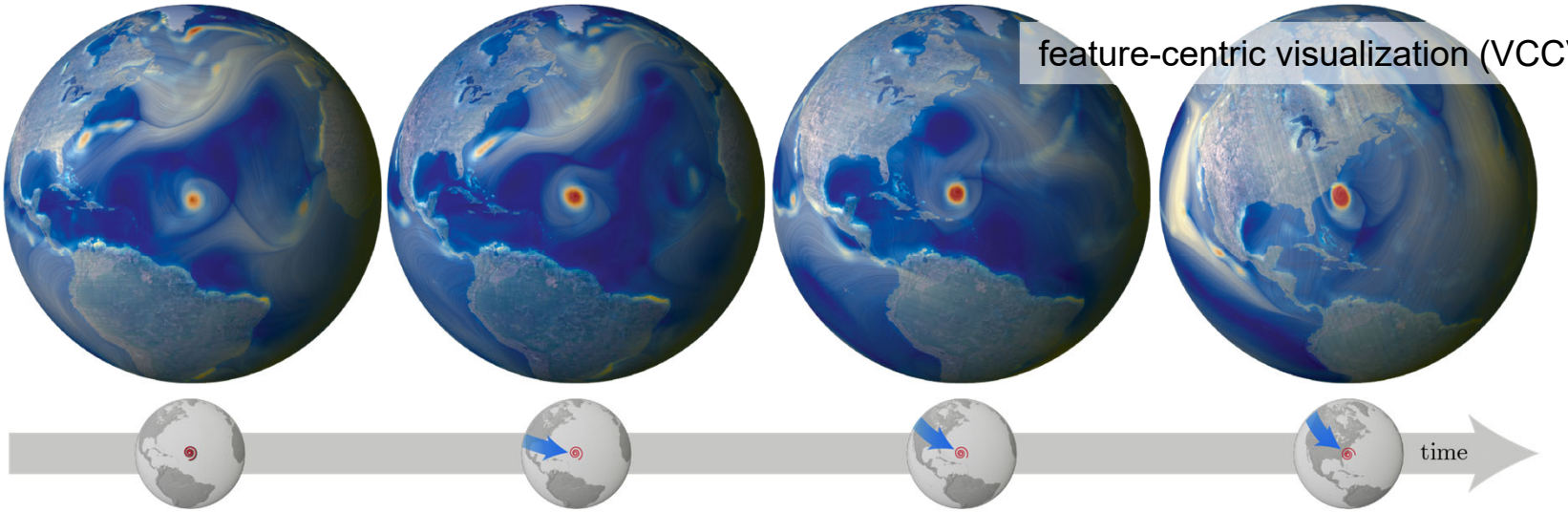
# Scientific Visualization – Examples



polar jet stream (NASA)



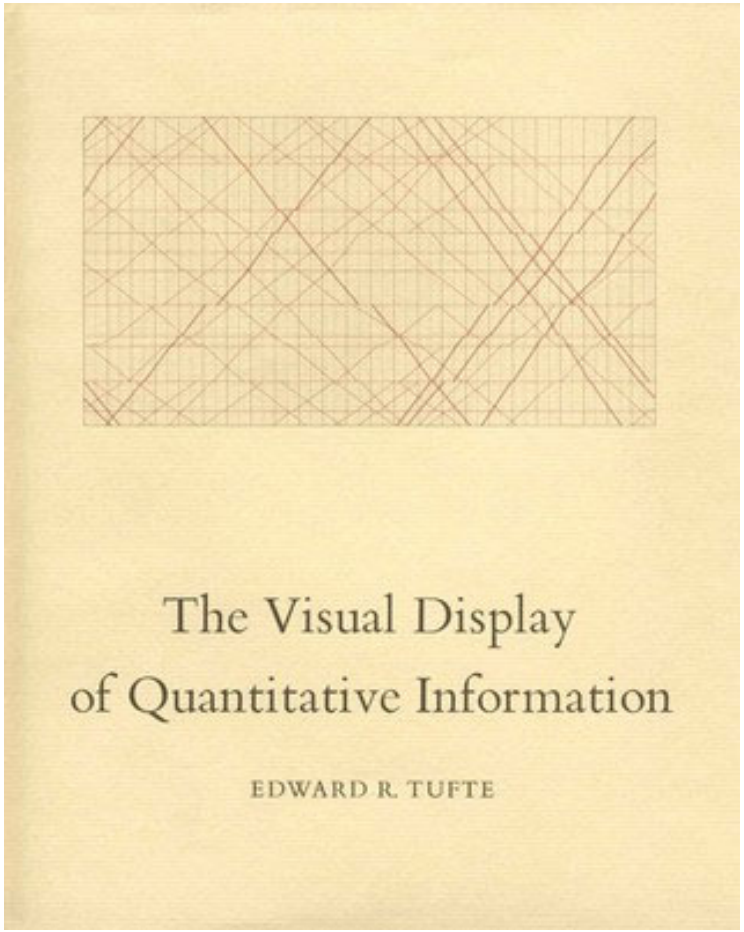
`https://earth.nullschool.net/`




feature-centric visualization (VCCVIS)

# Data Graphics / Info Graphics / InfoVis

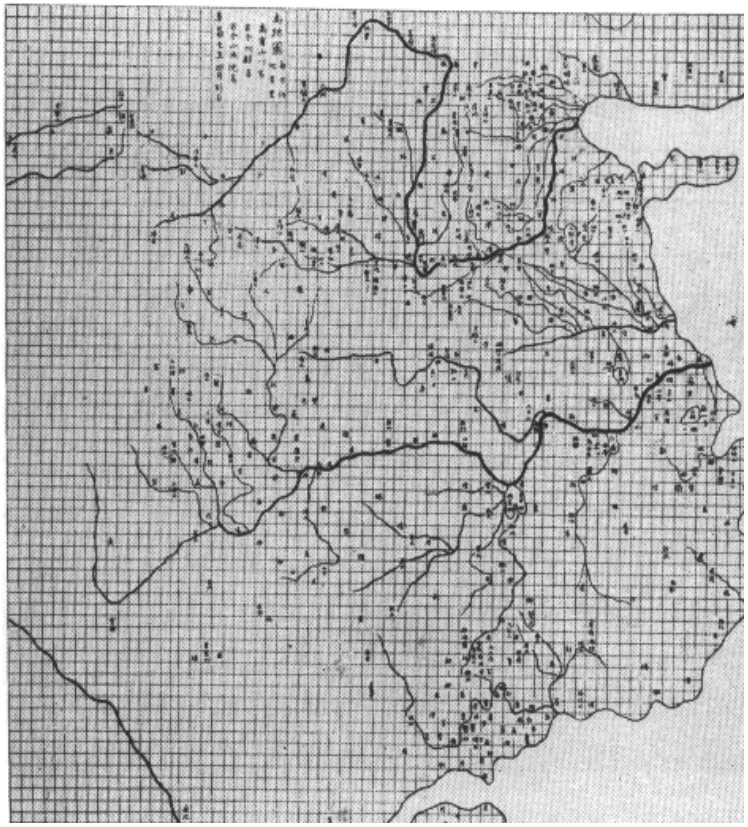
Famous book by Edward Tufte
(first edition 1983;
second edition 2001)




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

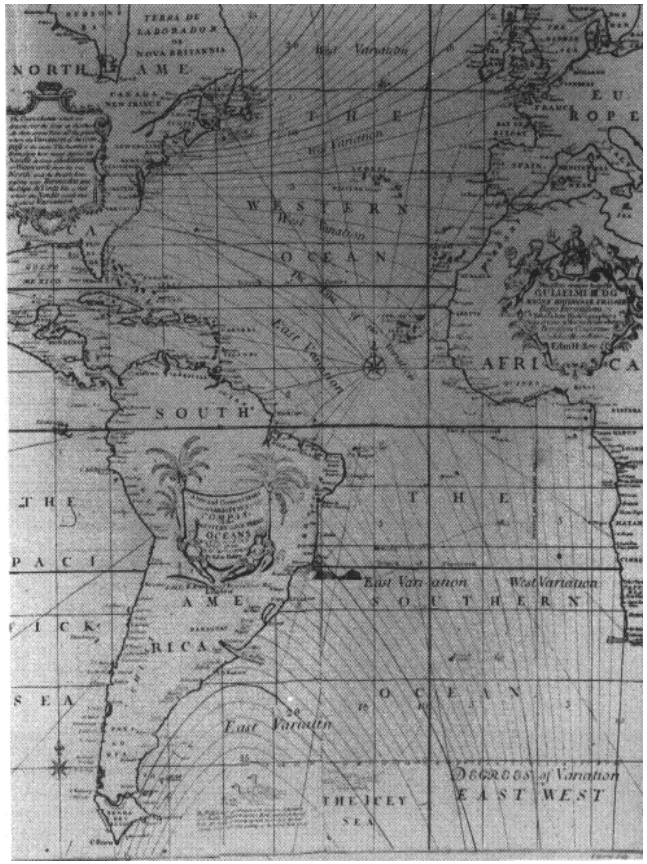


China, 1137

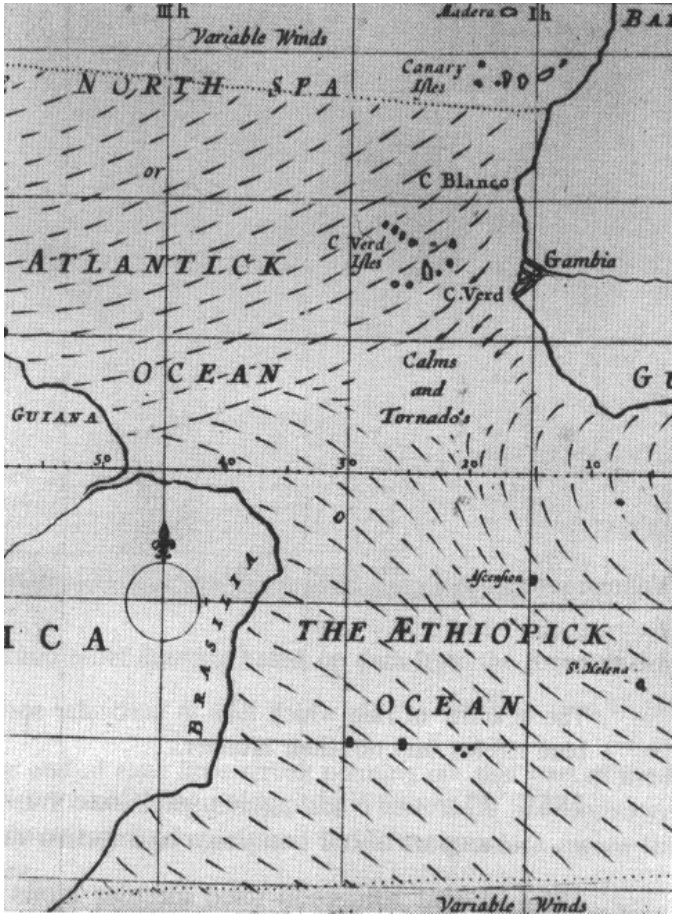
Geographical map using Cartesian coordinates

Grid with longitudinal and latitudinal lines

# Cartography

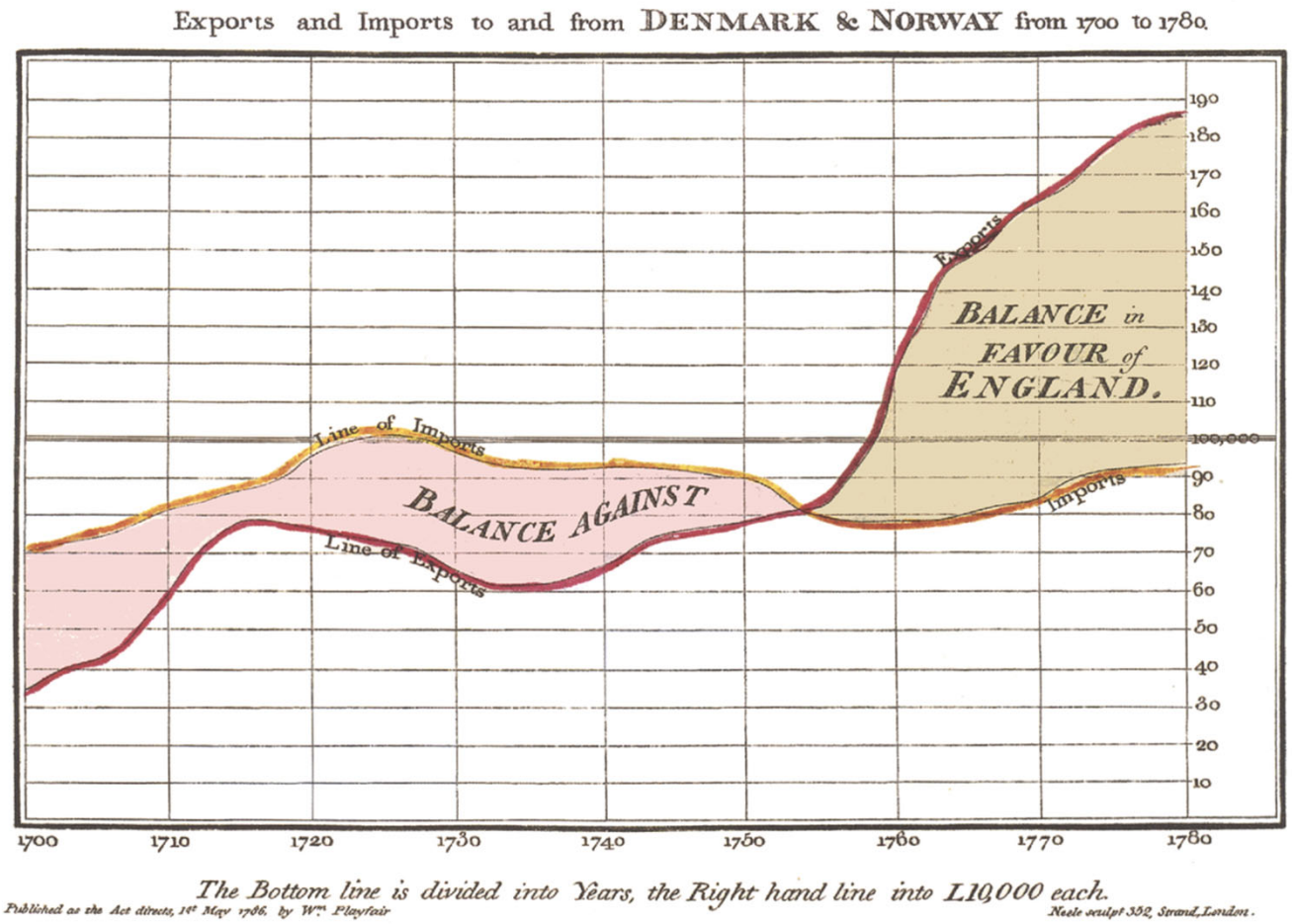



Isolines to visualize compass deviations



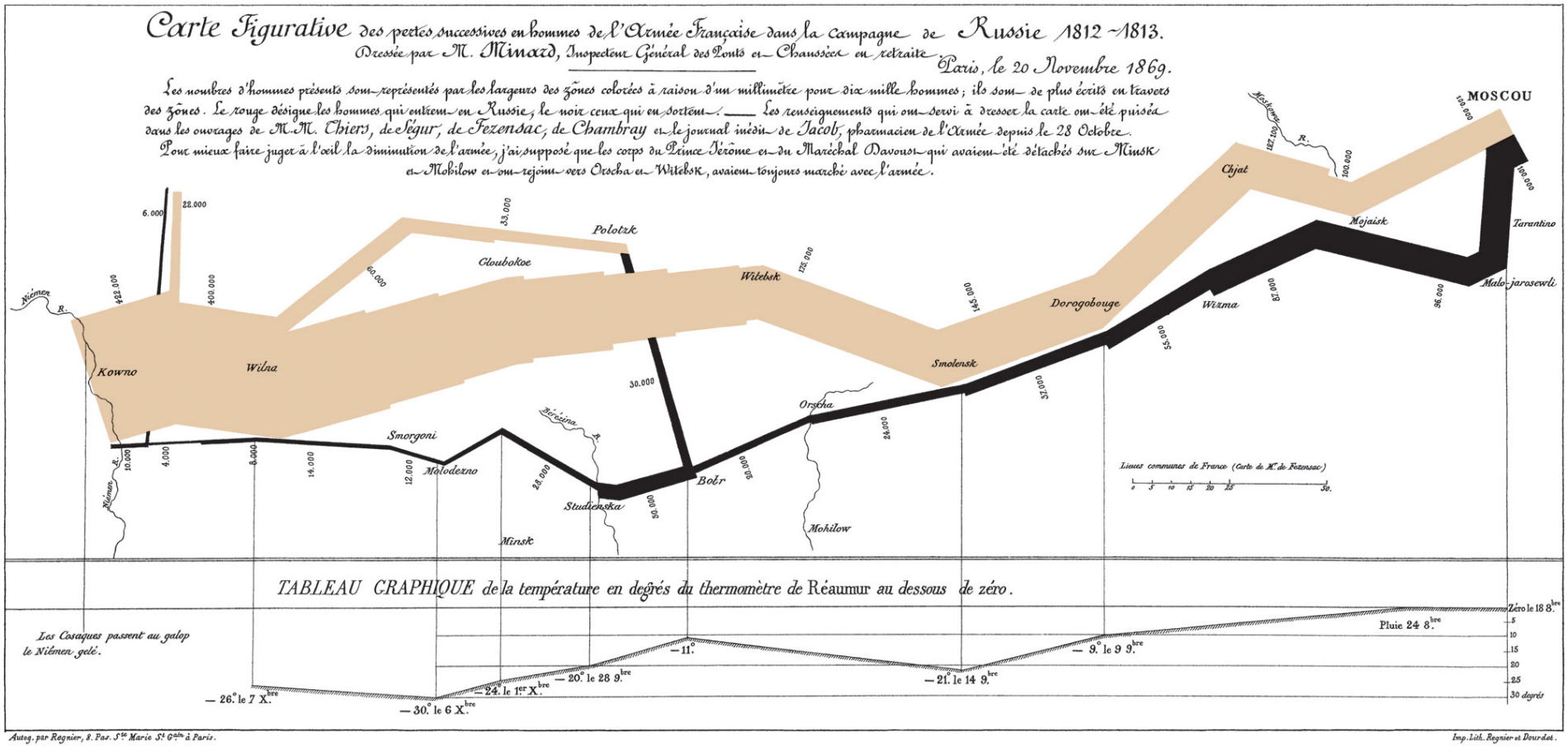

Wind flow visualization

# Business Graphics




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

# Russia Military Campaign of Napoleon




Charles Joseph Minard, 1869

# Cholera Epidemic in London

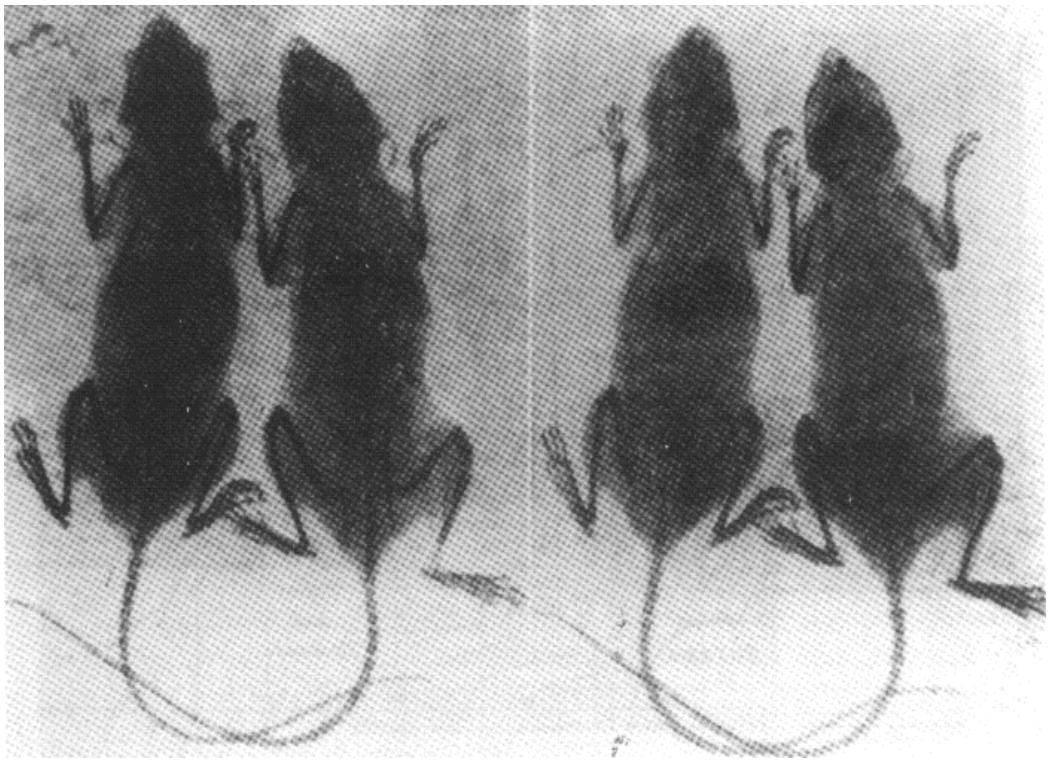
Dr. John Snow, 1854

Cartographic visualization

Correlation between water supply and disease incidents detected

# Visualization in Medicine

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



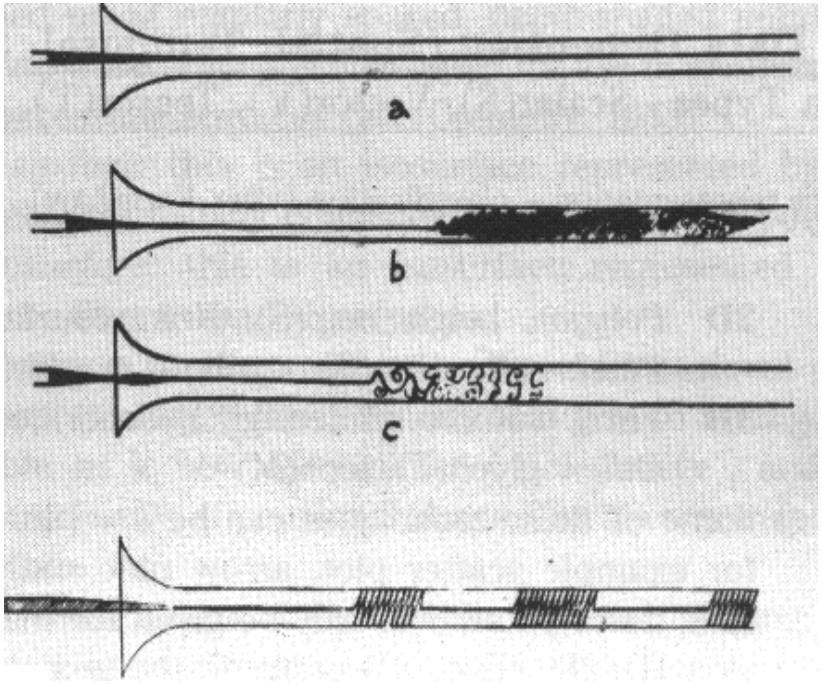
X-ray tomography

# 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 between the three can vary 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

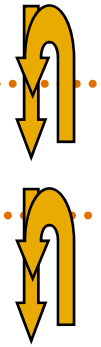
- Interactive visualization
  - Previously generated data are available
  - Visualization program allows interactive visualization of the data

  - Possibilities:
    choice, variation, parameterization of the visualization technique
  - Nowadays widespread
  - Focus of this course!

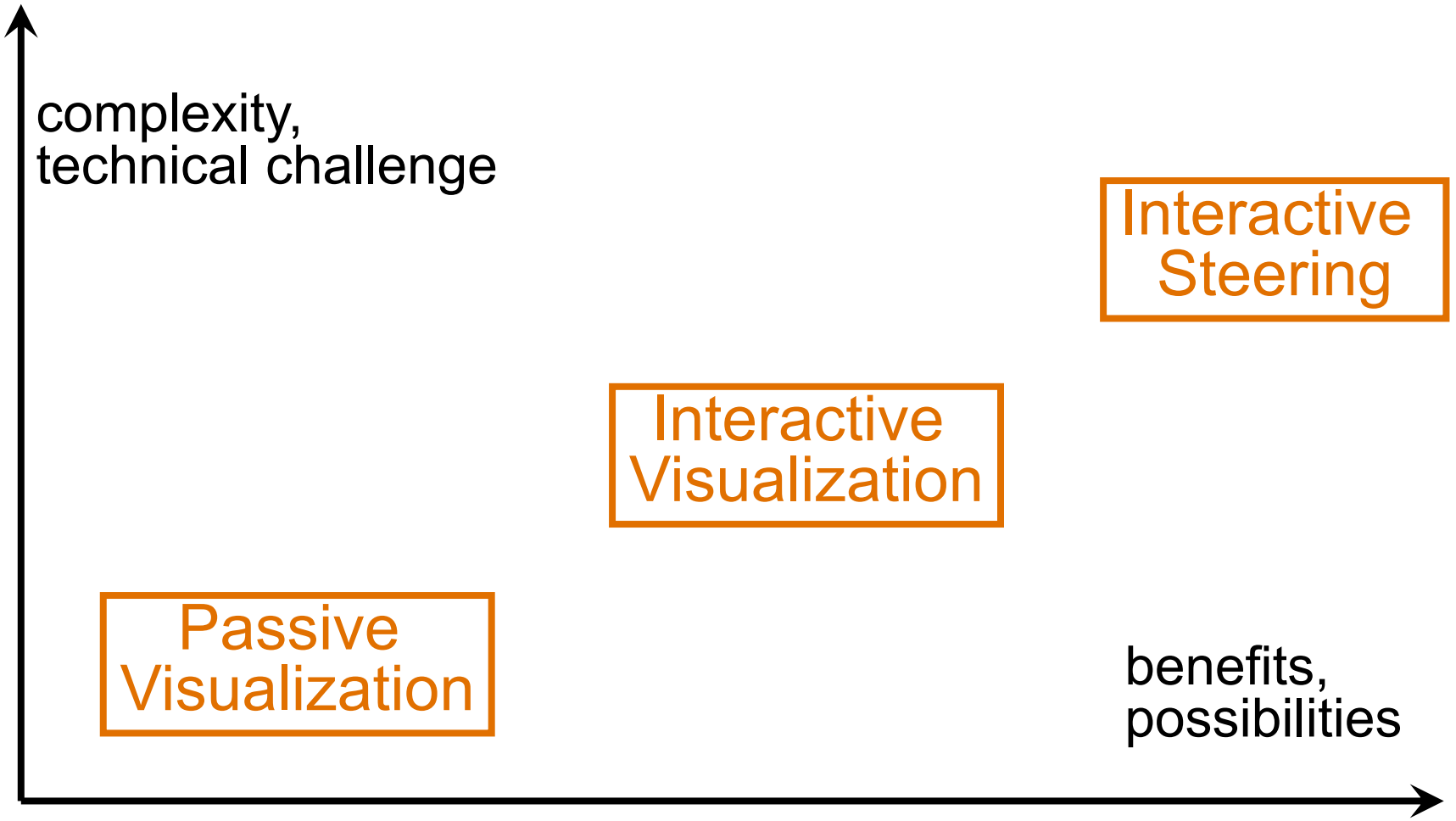
# Interactive Steering

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

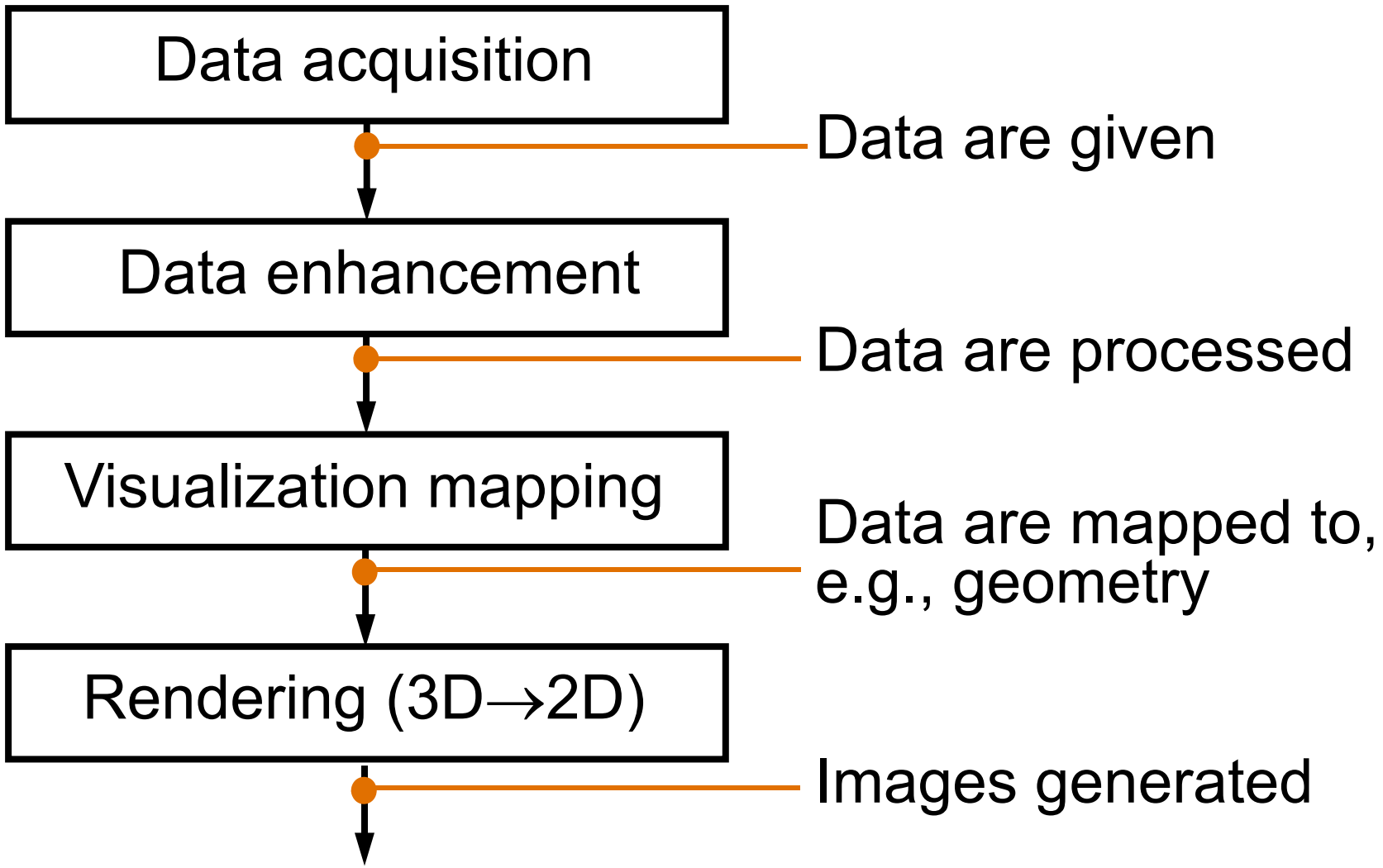


# Visualization Scenarios



# The Visualization Pipeline

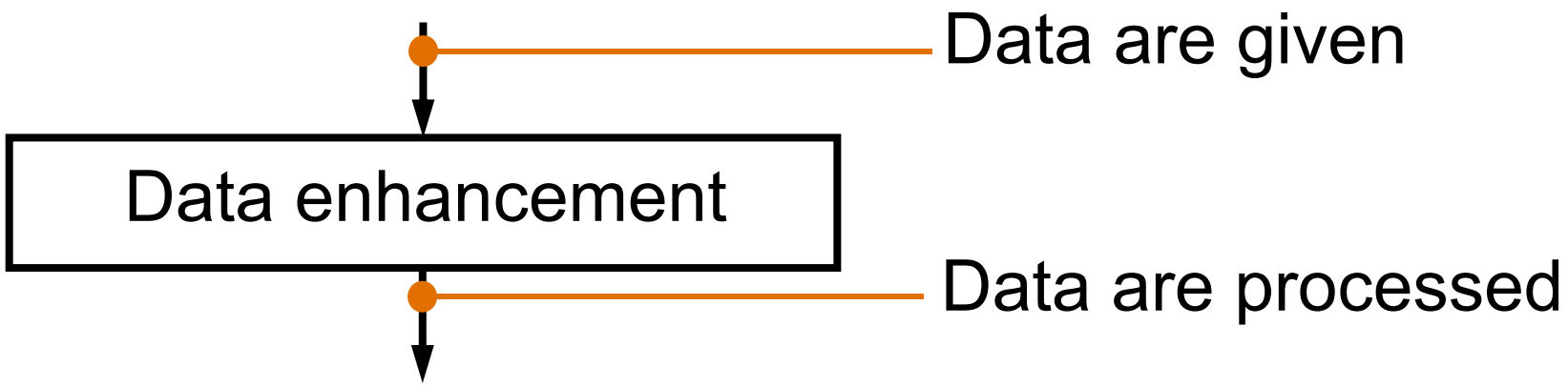
# The Visualization Pipeline – Overview



# The Visualization Pipeline – Stage 1

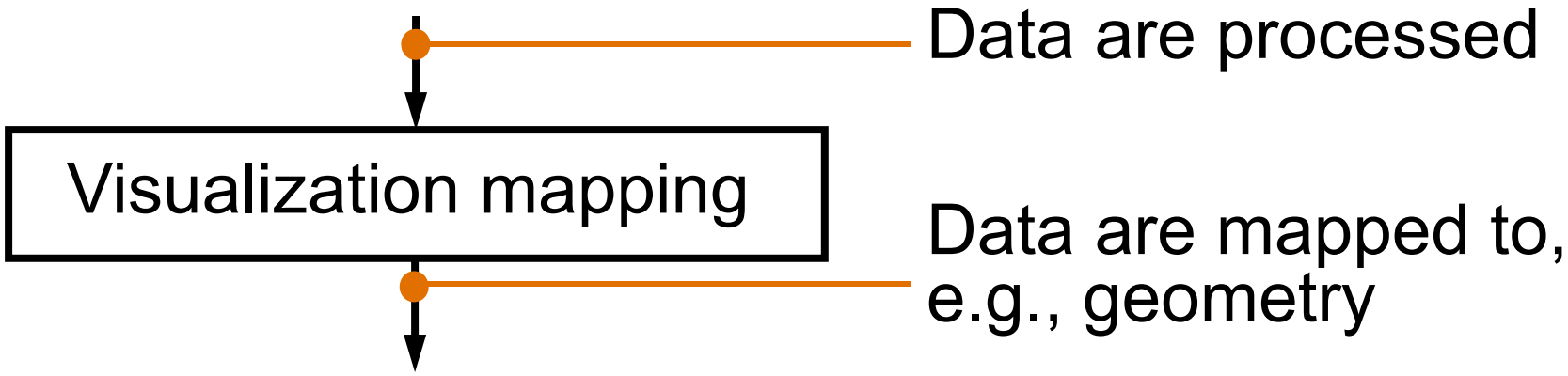

- Measurements, e.g., CT/MRI
- Simulation, e.g., flow simulation
- Modeling, e.g., game theory

# The Visualization Pipeline – Stage 2




- Filtering, e.g, smoothing (de-noising, …)
- Resampling, e.g., on a different-resolution grid
- Data derivation, e.g., gradients, curvature
- Data interpolation, e.g., linear, cubic, …

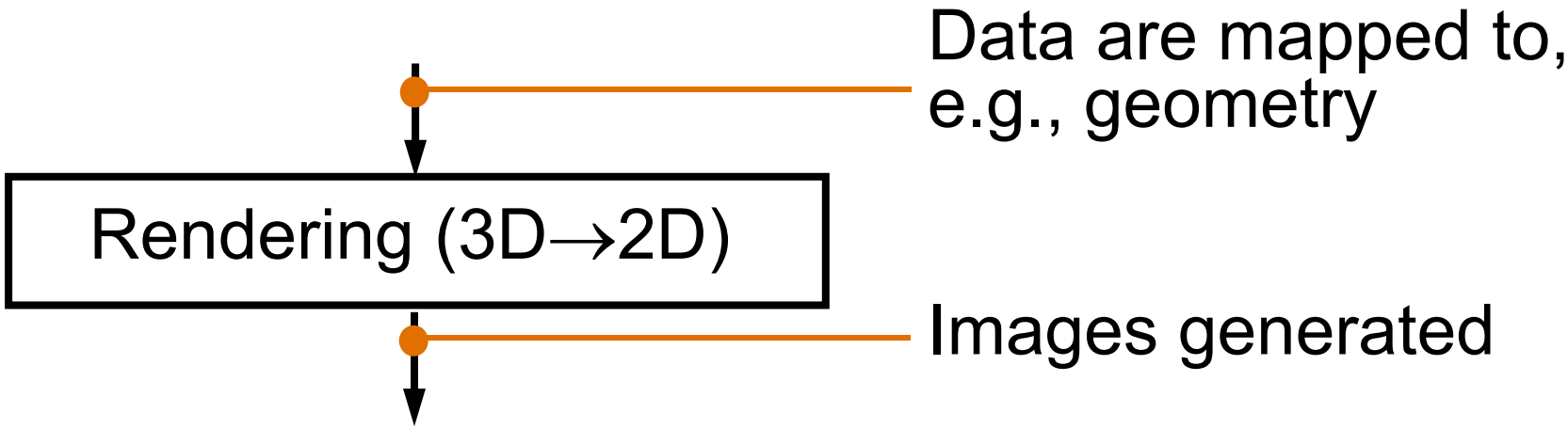
# The Visualization Pipeline – Stage 3




Make data “renderable”

- Iso-surface calculation
- Glyphs, icons determination
- Graph-layout calculation
- Voxel attributes: color, transparency, …

# The Visualization Pipeline – Stage 4




Rendering = image generation with computer graphics

- Visibility calculation
- Illumination
- Compositing (combine transparent objects, …)
- Animation

# Thank you.

Thanks for material

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