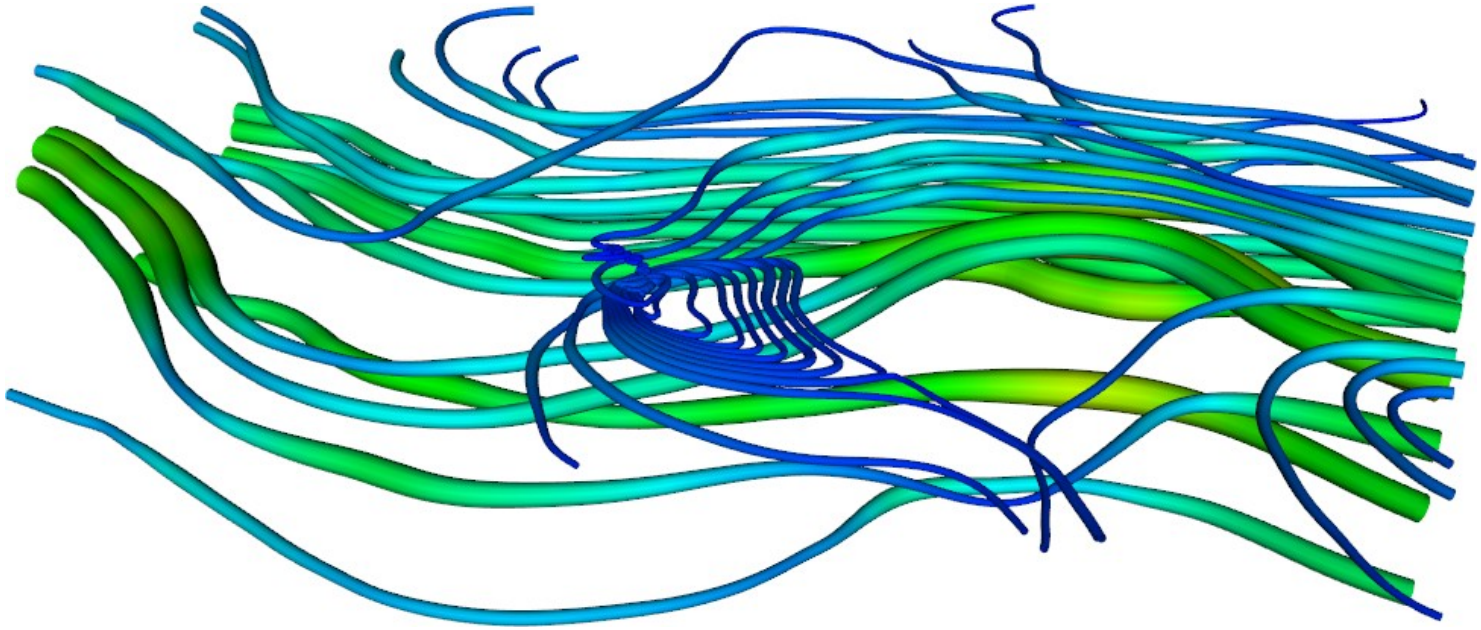
Scientific Visualization

Autumn 2015

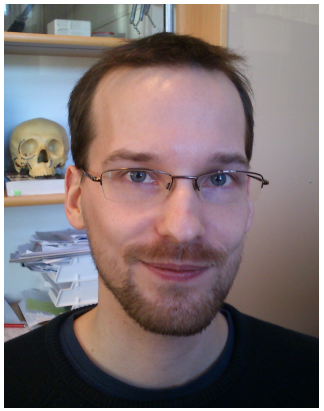


Teachers

Anders Hast (head teacher)
Associate Professor in computer graphics/visualization

Stefan Seipel (teacher)
Professor in computer graphics

Johan Nysjö (lab assistant)
PhD student in medical image analysis

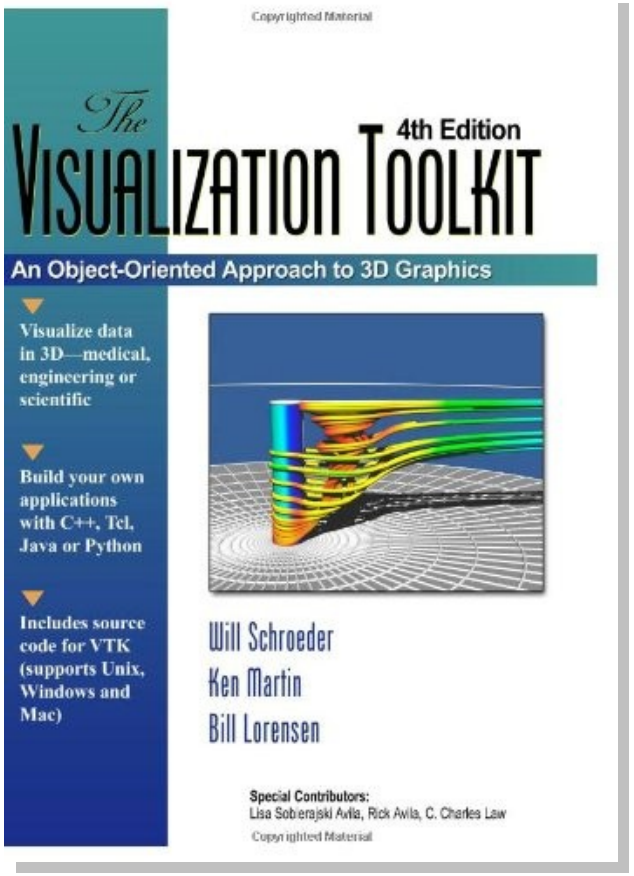


Formalities

- 2 mandatory assignments
- 1 project (also mandatory)
- 1 case study (seminar)
- Written exam (5 hours)
- All information and material is (or will be) on Studentportalen
- If you haven't registered for the course yet, please do!

Course book

Visualization Toolkit: An Object-Oriented Approach to 3D Graphics, 4th Edition



Order the textbook directly from the publisher Kitware, Inc. or via Amazon.com

“A picture is worth a thousand words”

Refers to that complex stories can be described with a single image.

This expression is valid also in scientific visualisation.

When **large** and **complex** data sets are resulting from experiments and computations, visualisation is a way to give deeper **insight** and **knowledge**.

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```
# vtk DataFile Version 3.0
vtk output
BINARY
DATASET STRUCTURED_POINTS
DIMENSIONS 256 256 124
SPACING 0.9 0.9 0.9
ORIGIN 0 0 0
CELL_DATA 7998075
POINT_DATA 8126464
COLOR_SCALARS ImageFile 1
^D^E^C^G^D^B^D^B^B^C^D^E^D^E^C^C
^D^C^C^C^C^E^D^C^A^B^B^B^F^A^C^E
^D^D^E^A^A^C^B^B^E^B^A^A^E^B^E^E
^A^C^C^G^C^D^F^B^D^E^@^G^C^D^D^C
^D^C^F^C^B^E^E^E^B^C^C^B^C^B^C^B
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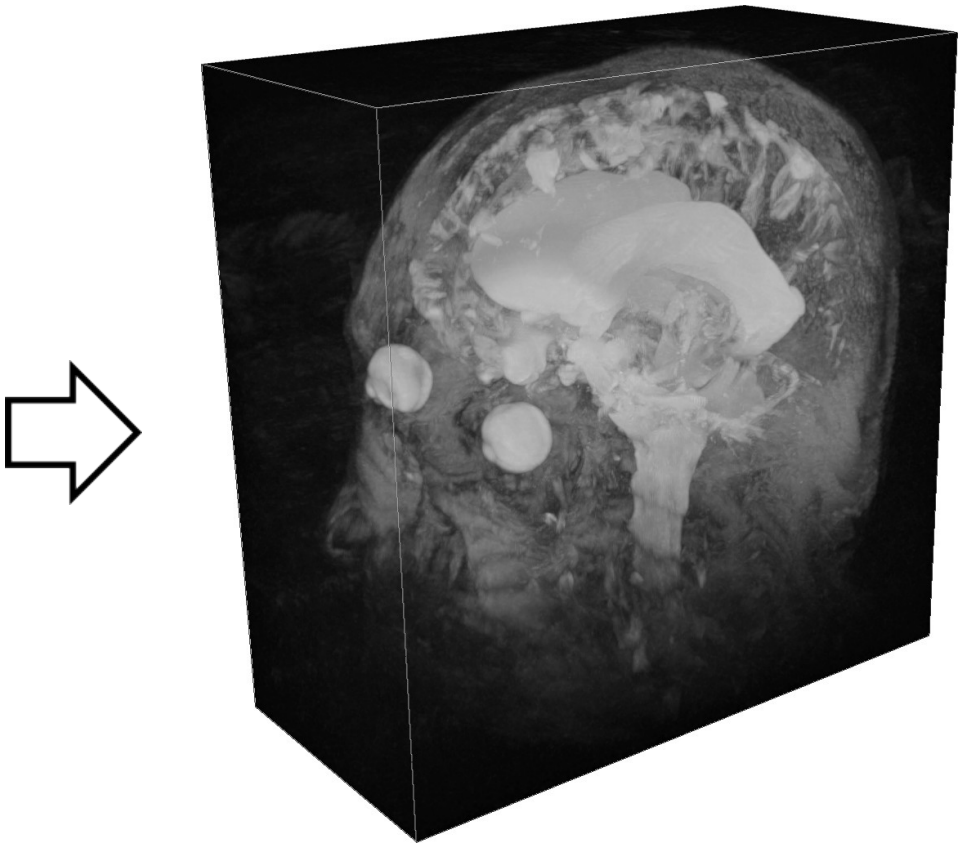
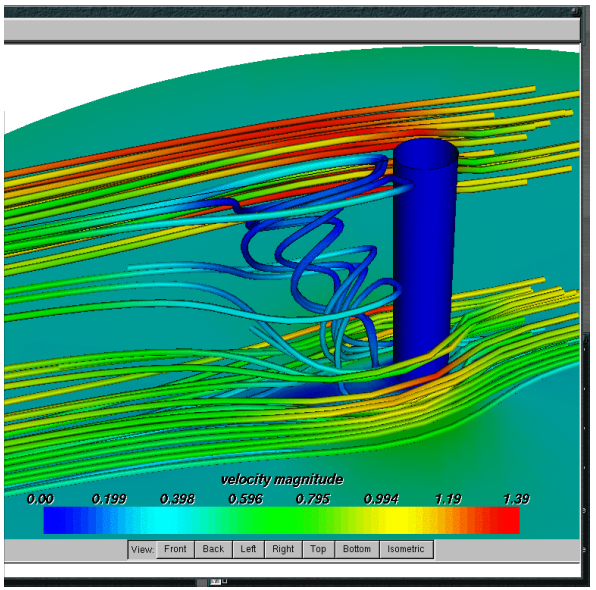


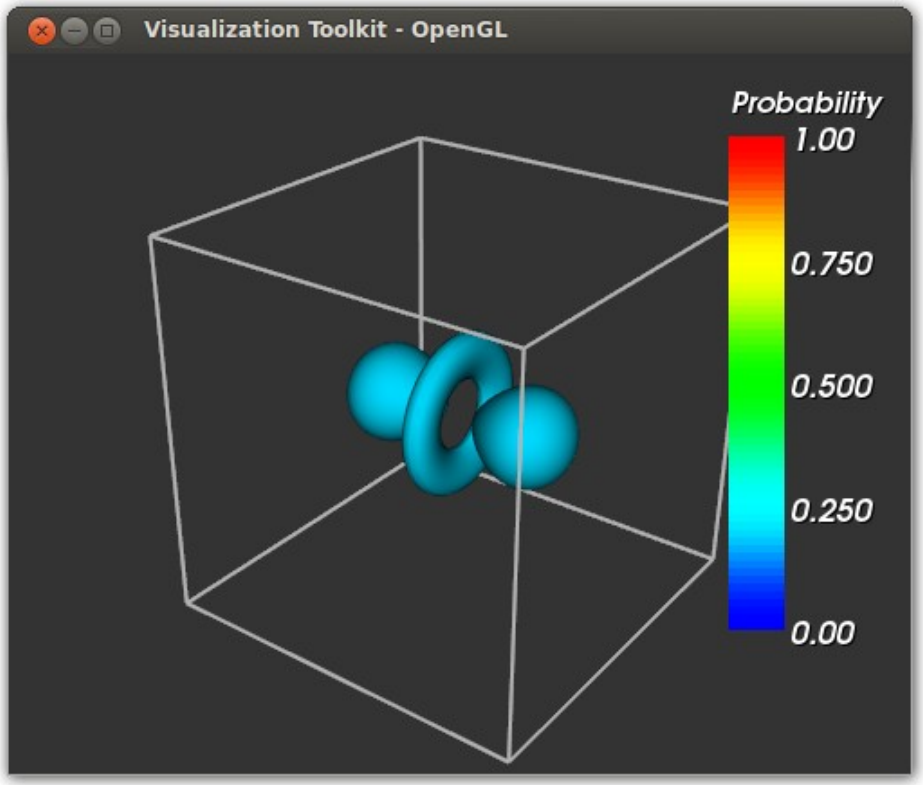
Scientific visualization

- Scientific visualisation is the process of **exploring**, **transforming**, and **viewing** data as images
- The data describes natural or physical phenomena or quantities
- Often observed (measured) or simulated data
- Visualisation is often interactive
- We are (usually) not trying to create realistic images, but to visualise data in an informative way
- Application dependent

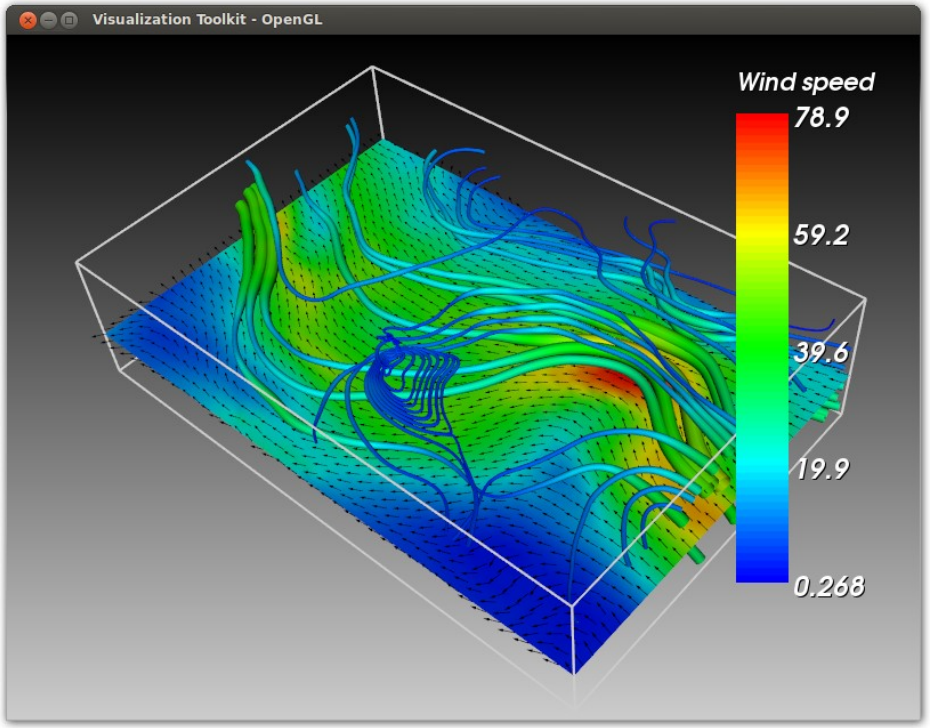


- This course will mainly focus on visualization of three-dimensional (3D) data
- You will learn how
  - to select appropriate visualization methods, possibilities and limitations of methods,
  - and to use visualisation toolkits.
- A focus will be on using script programming (Python) in combination with VTK (the Visualisation Toolkit).

Assignment 1

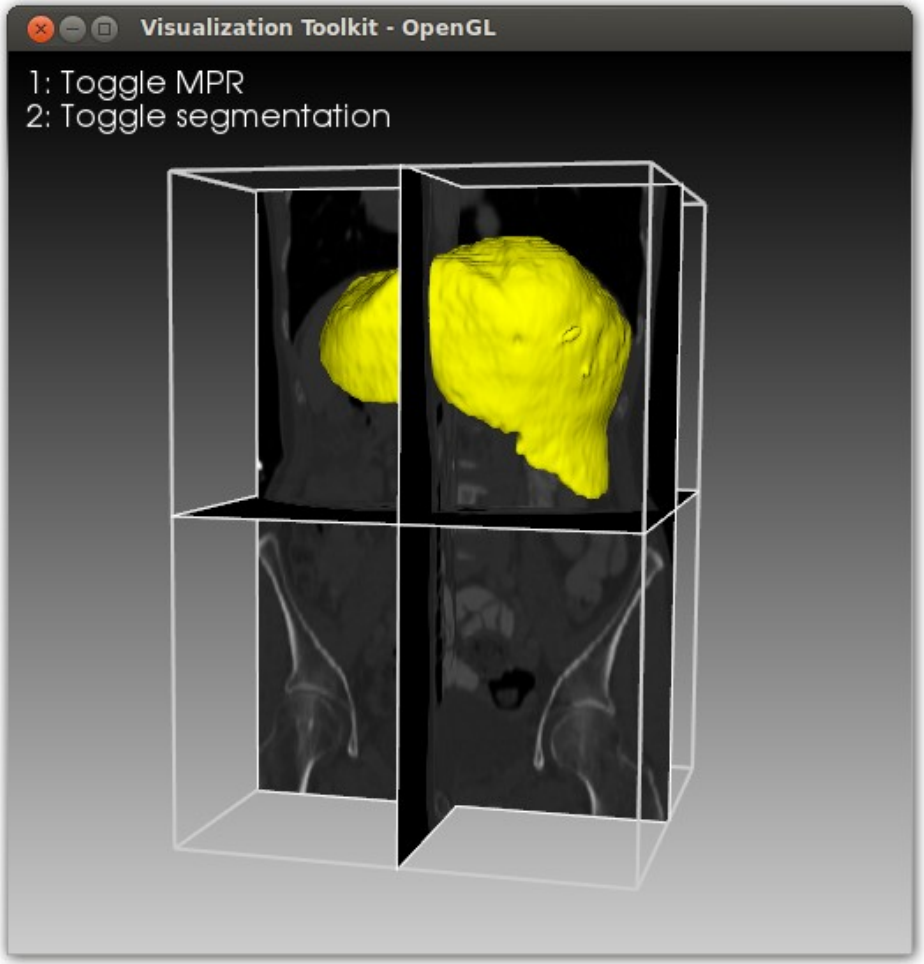


Isosurface rendering

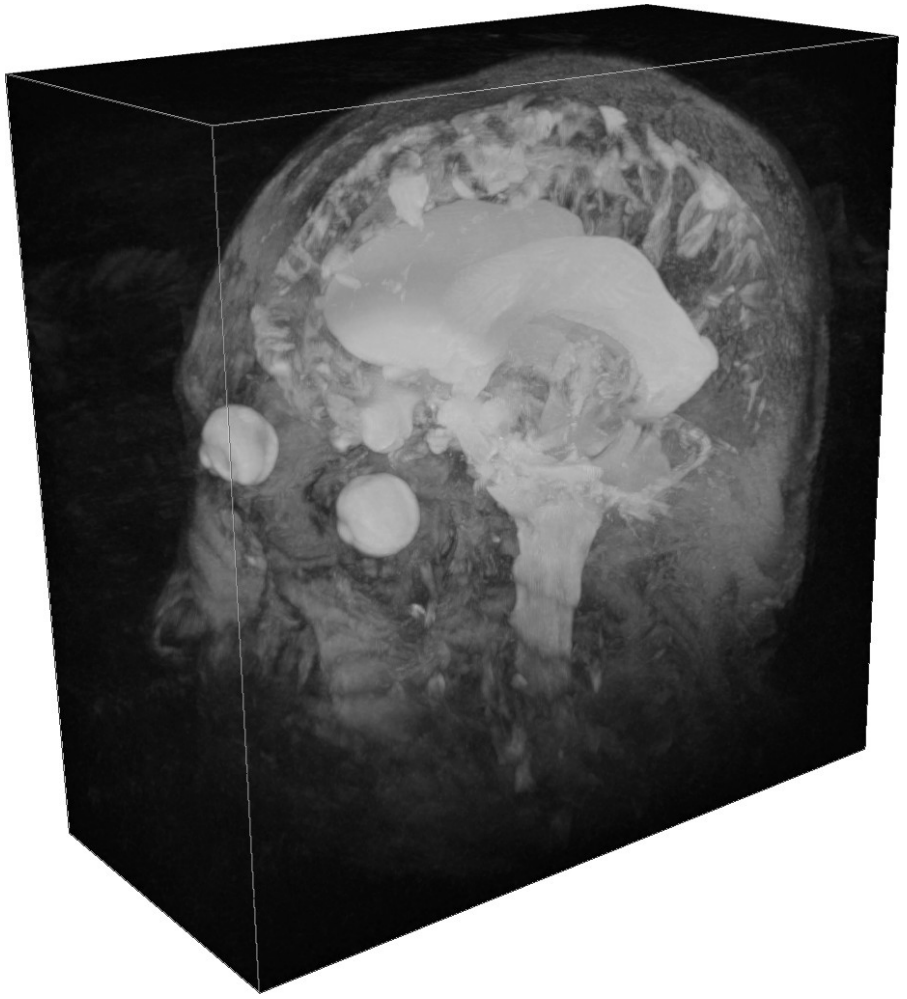


Visualization of air currents and molecular data

Assignment 2

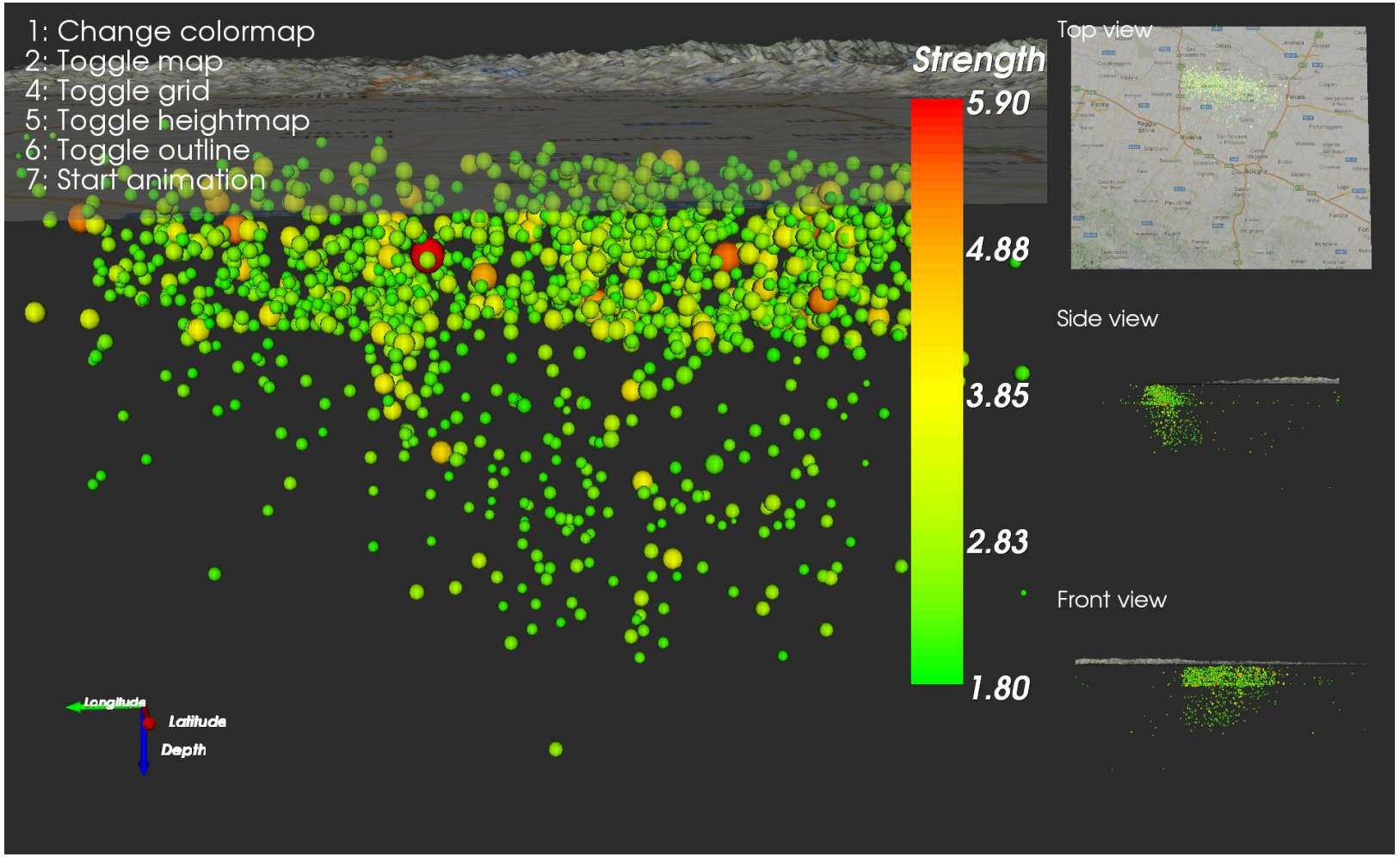


MPR visualization of CT data



Volume rendering

Project



Visualization of earthquake data from northern Italy

Visualization purposes

- Communication of information (emphasizing, narrating)
- Improve understanding (illustrating, interpreting, finding)
- Decision support (analyzing, extrapolation)
- Answering questions (diagnosing, interpreting)
- Support creativity (inspiration)
- Making new discoveries through interaction!

General development of visualization

- Rather new discipline still developing into sub-areas
- Tool users vs. tool developers
- Collaboration among computer scientists and computational scientists
- Faster computers, high-speed networks, new user-interfaces

Visualizations help us getting insight

- Takes advantage of human sensory abilities
  - Pattern recognition, trend discovery, etc.
- Useful when
  - numeric data is to be understood
  - complex relations must be understood
  - multiple variables have to be analyzed
- Visualization is not a substitute to, but a **complement** to, statistical analysis and other quantitative methods

Graphs are one type of visualization

Length	Width
5.1	3.5
4.9	3.0
4.7	3.2
4.6	3.1
5.0	3.6
5.4	3.9
4.6	3.4
5.0	3.4
4.4	2.9
4.9	3.1

Data from the Iris flower dataset

Graphs are one type of visualization

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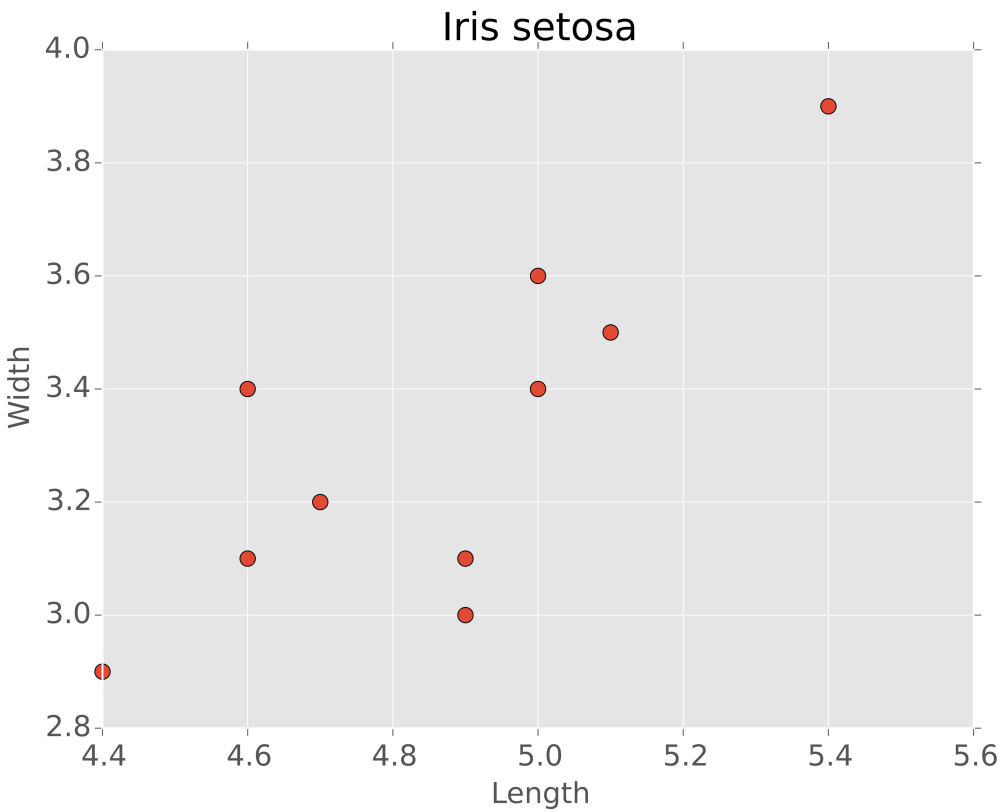
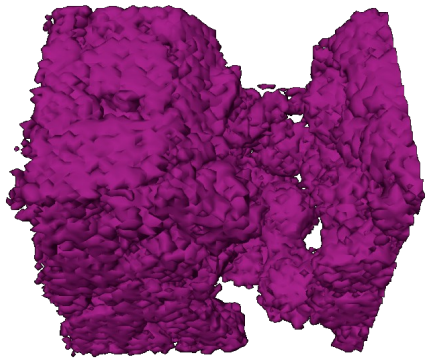
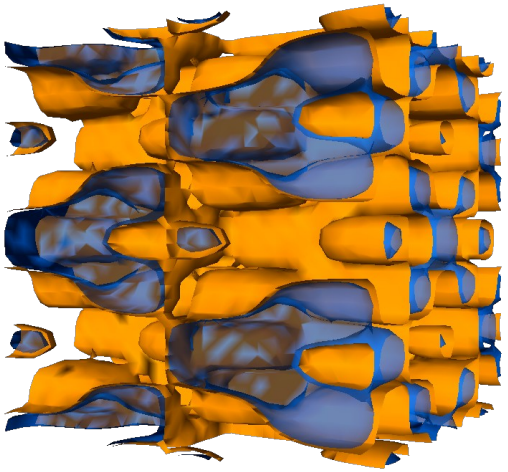


Data from the Iris flower dataset

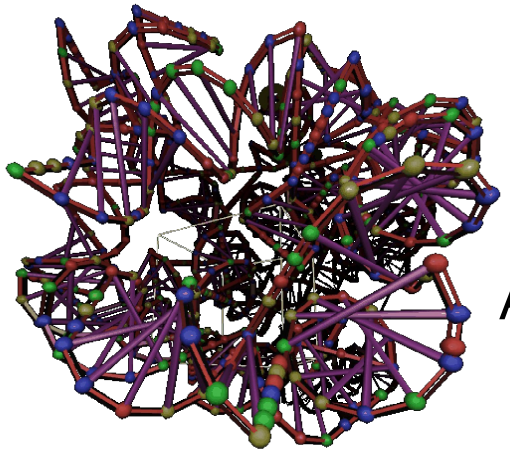
Some more sophisticated examples



Nuclear, Quantum, and Molecular Modeling



Structures, Fluids, and Fields



Advanced Imaging and Data Management

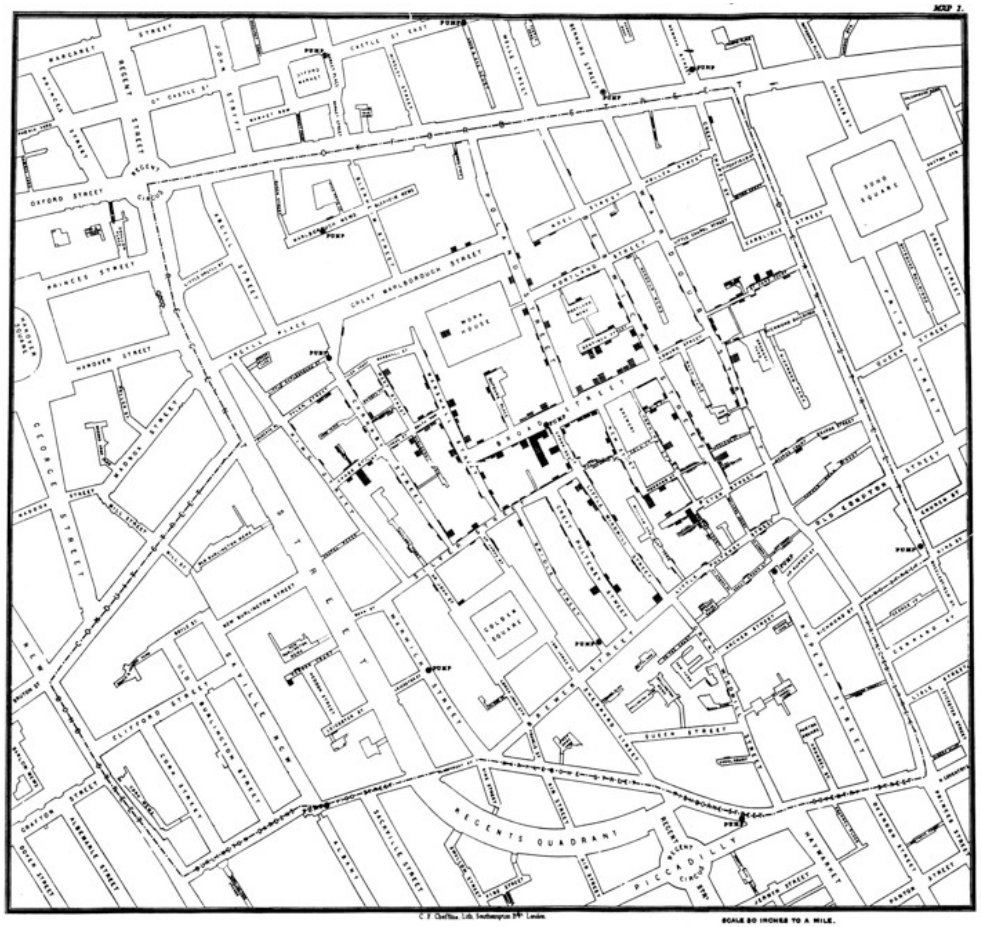
Classical example

Dr. John Snow; The Cholera Epidemic in London 1854

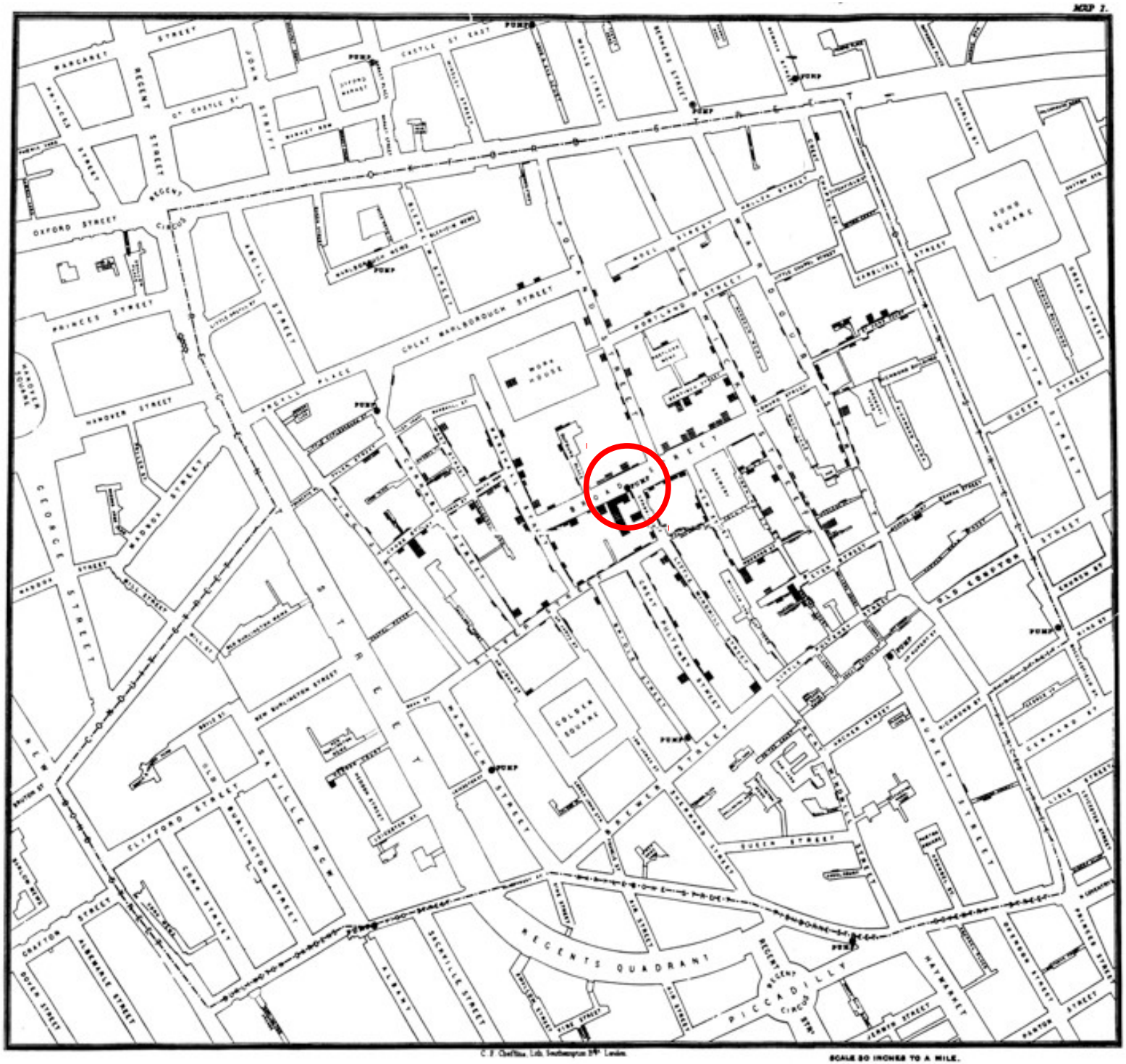
Used *spot-map* to graphically depict cholera incidents.

Spatial clusters *led to him to the hypothesis* that cholera was communicated through contaminated water.

Identification and removal of contaminated pump led to reduced mortality and partly confirmed his hypothesis.



Note: The visualisation did not prove anything. But was influential to the development of the novel hypothesis which was later proved true.


MAP 7.
OXFORD STREET
REGENT STREET
PRINCES STREET
GREAT MARLBOROUGH STREET
HANOVER STREET
GEORGE STREET
BROAD STREET
POLAND STREET
NEWMAN STREET
GOLDEN SQUARE
SOHO SQUARE
REGENTS QUADRANT
PICCADILLY
WORK HOUSE
PUMP
SCALE 30 INCHES TO A MILE.

Ch 3: Computer Graphics

- Computer graphics aims at creating pictures by mimicking the image formation process that occurs in conventional photography.
- Foundation of scientific visualization

The Utah Teapot

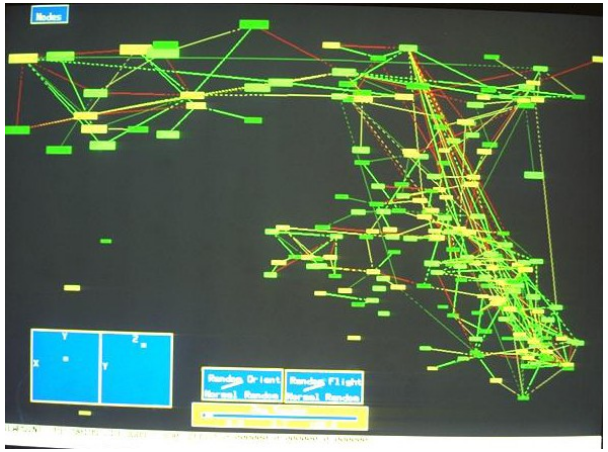
Computer Graphics examples

Simulate and visualize real things

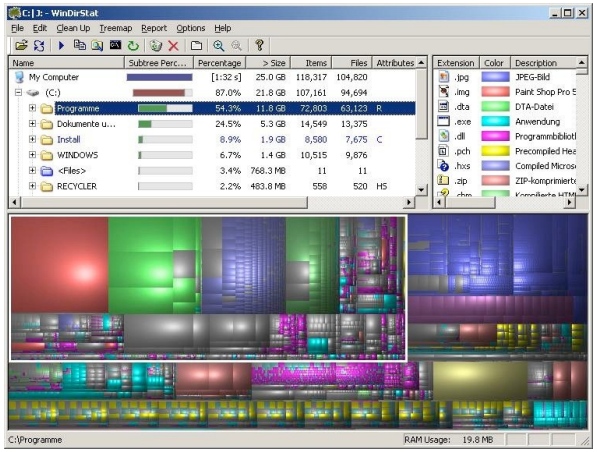
Interior design (Linus Karlsson, CCG 2011)

Interactive Games

Make visible what cannot really be seen



Visualisation of semantic networks in SemNet.



Hard-Disk utilization (WinDirStat)

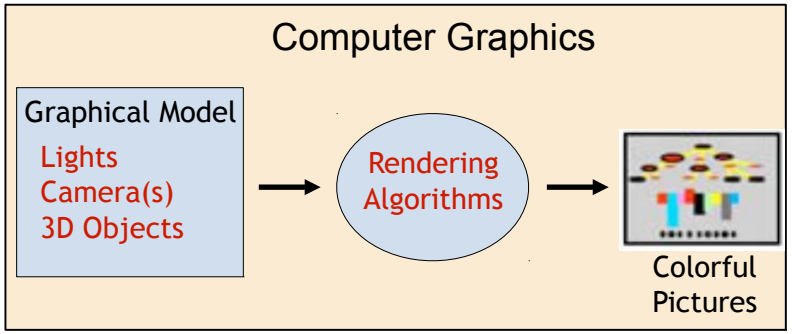
Computer Graphics

What is needed to mimic photography, i.e., to render images with a computer?

- Virtual objects: 3D models, geometry, material properties
- Virtual light sources: position, color, attenuation, etc.
- Virtual camera: position, direction, lens projection
- Illumination model: Rendering algorithms that model the propagation of light and its interaction with objects in the scene.

Computer Graphics & Visualization

- Graphical rendering is one pillar of Scientific/Information Visualisation



Computer Graphics & Visualization

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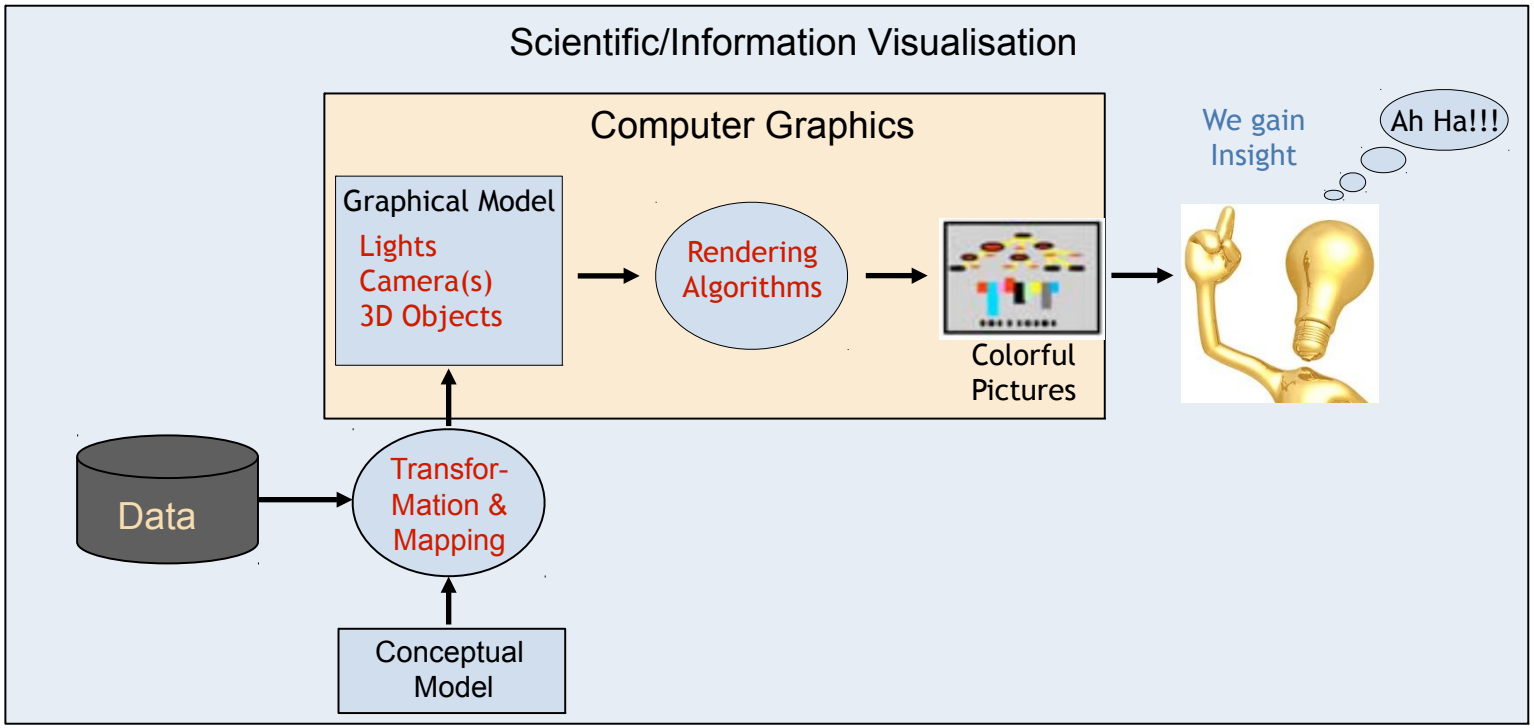

Visualisation is more than computer graphics!

Computer Graphics

- Anders will tell you more about this topic in a later lecture

Ch 4: The Visualization Pipeline

- Visualization addresses the issues of
  - **Transformation**: converting data from its original form into graphics primitives and into computer images
  - **Representation**: the internal data structures and the graphics primitives

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^D^C^C^C^C^E^D^C^A^B^B^B^F^A^C^E
^D^D^E^A^A^C^B^B^E^B^A^A^E^B^E^E
^A^C^C^G^C^D^F^B^D^E^@^G^C^D^D^C
^D^C^F^C^B^E^E^E^B^C^C^B^C^B^C^B
^C^C^F^E^F^C^D^A^A^C^F^D^D^E^E^B
```
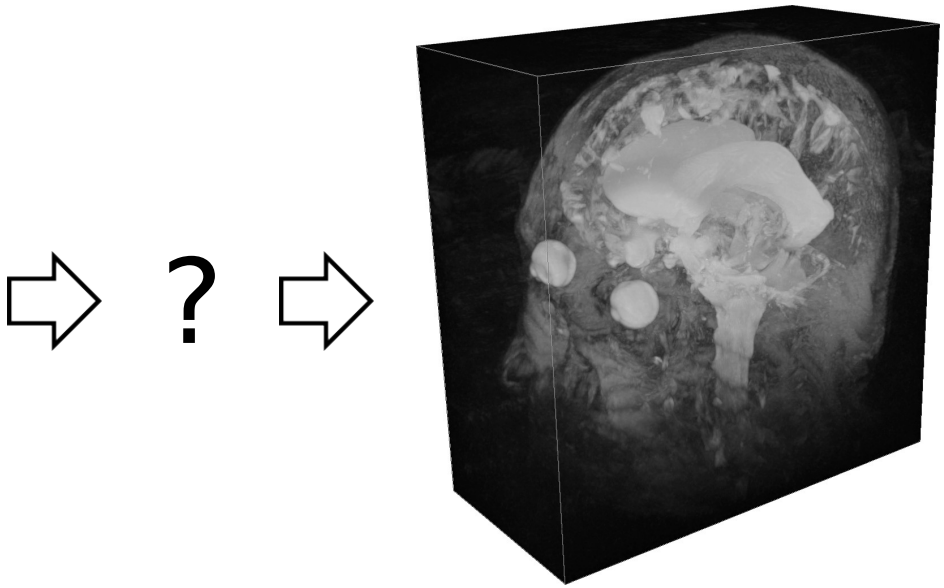



Visualization pipeline, cont.

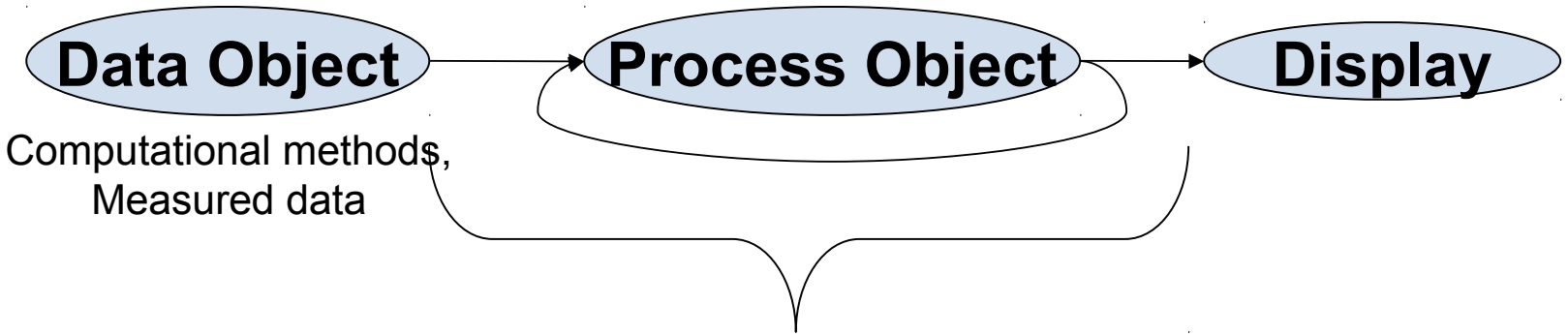
- The pipeline consists of
  - objects to represent data
  - objects to operate on data
  - indicated direction of data flow (arrow connections between objects)

Process objects

- Operate on input data to generate output data
  - Output data can be new data or new form

- **Source objects**
  - initiate (read, generate) visualization data flow
- **Filter objects**
  - maintain visualization data flow
- **Mapper objects**
  - terminate (write, graph) visualization data flow

A visualization pipeline

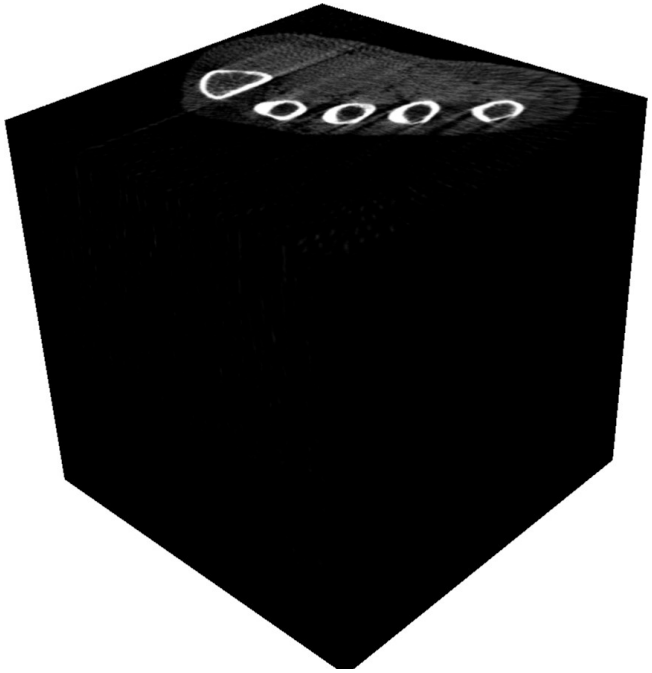


Executing the pipeline

- Causing each process object to operate
- Most frequent executions due to user interaction
  - change parameters of process object
  - change input to process object
- For efficiency, only execute the process objects whose input has changed
- Synchronization required

Conclusion

- Visualisation helps to understand the data and get insight on the data
- It is also a tool to discover the data and find “hidden truths” in the data
- Visualisation uses Computer Graphics



Next lecture

- Python and VTK programming