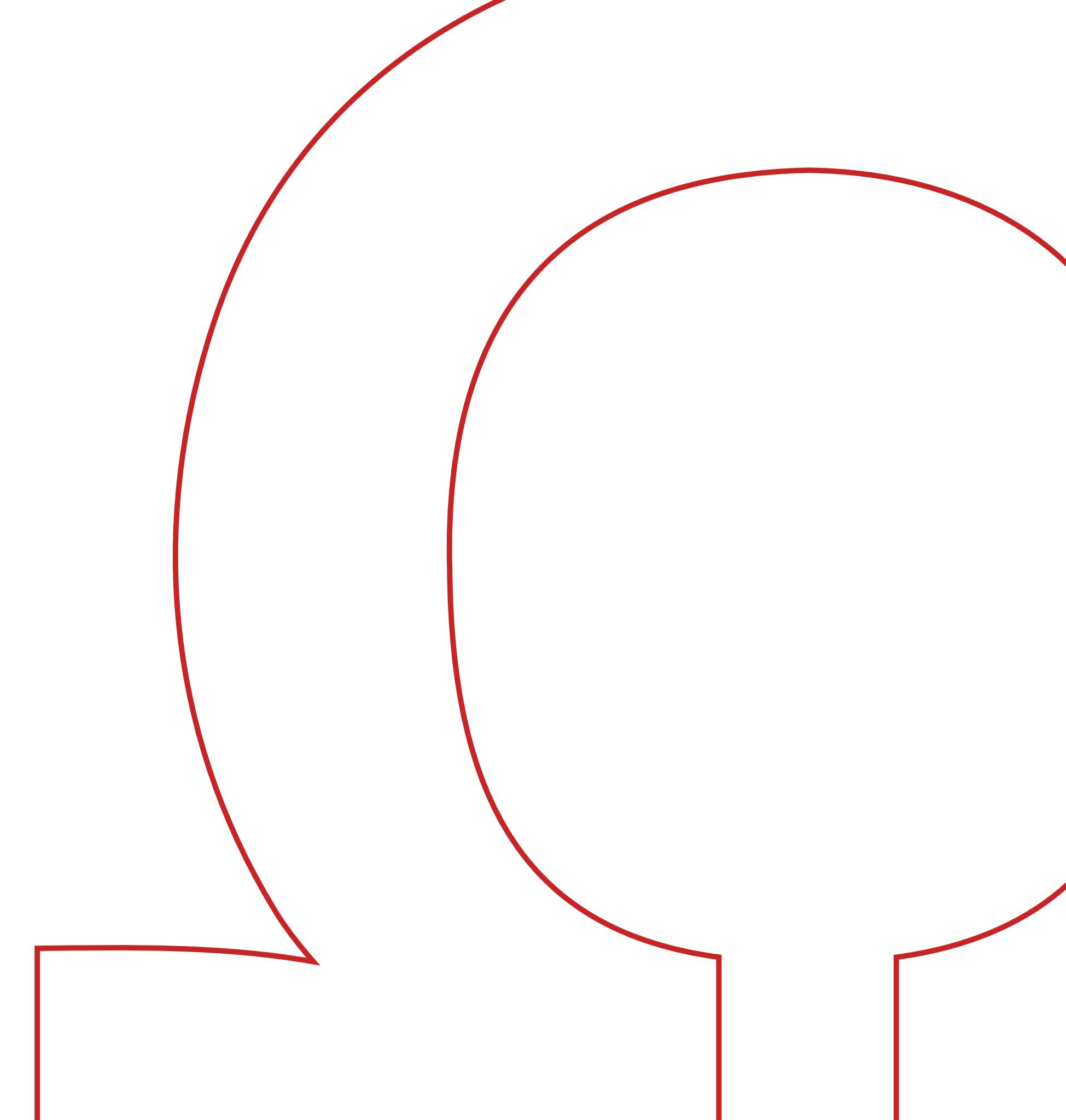




# Visualization

Prof. Dr. Matthias Teßmann  
Technische Hochschule Nürnberg  
Department Computer Science  
Summer Term 2023



# **Moodle**

<https://elearning.ohmportal.de/course/view.php?id=12692>

Registration Password: **PiXXL\_2023**

# Contact

## Prof. Dr. Matthias Teßmann

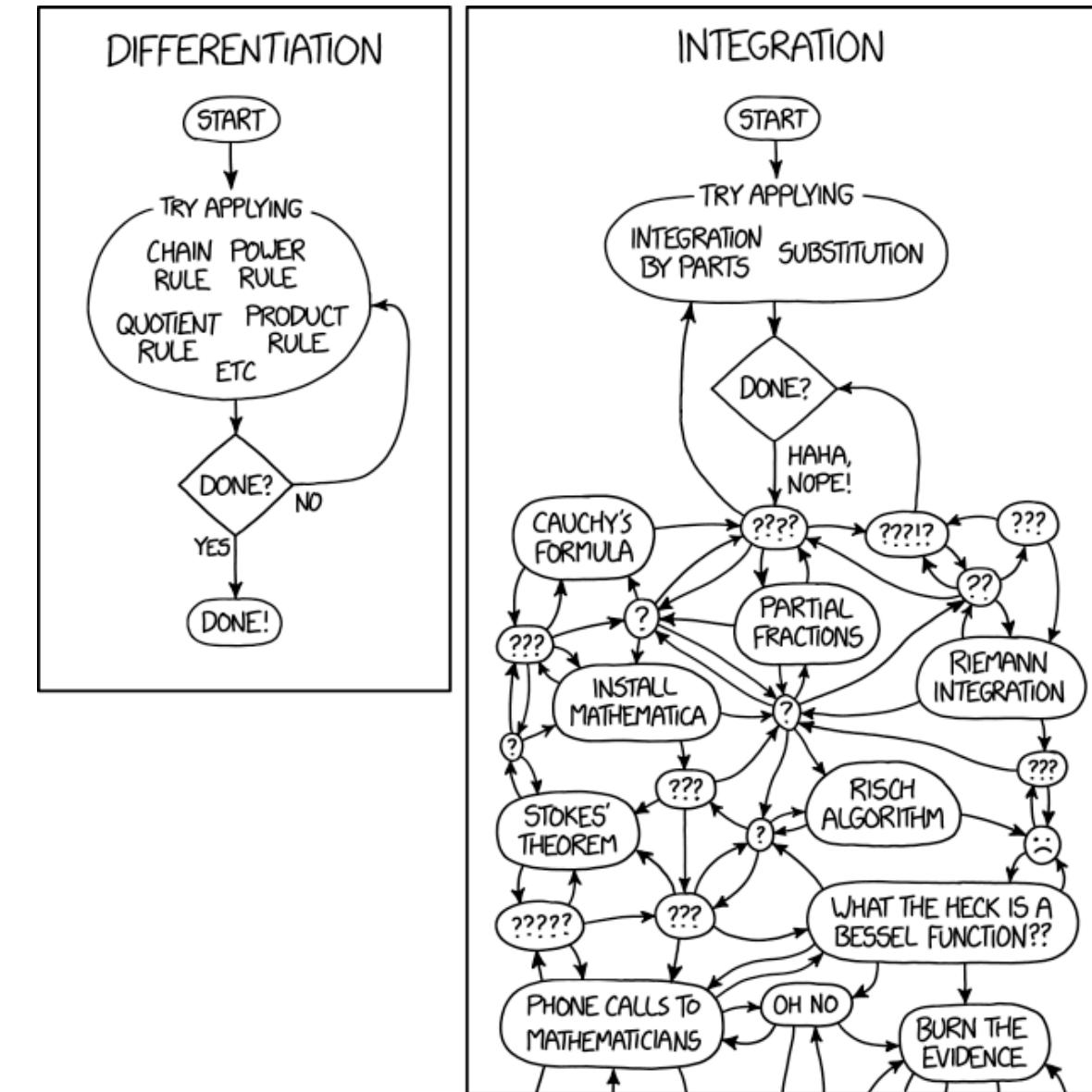
- Mail: matthias.tessmann@th-nuernberg.de
- Tel.: +49 911 5880-1193
- Office: HQ.411 (appointments **online only**)
  - Contact me via mail or MS Teams chat for an appointment if you need to
- You can ask simple questions via MS Teams chat
  - But you can and should also ask during the lecture and especially the exercises
  - Also: use the Q&A forum in Moodle

# Organization

- Lecture
  - Tuesday, 13:00h – 14:30h, HQ.405
- Exercises
  - Wednesday, 13:00h – 14:30h, HQ.205
- Exam
  - Written exam / online exam at the end of semester (90 minutes)
    - You can bring 5 pages self-compiled material and a calculator
    - Only students assigned to this FWPF can take the exam!

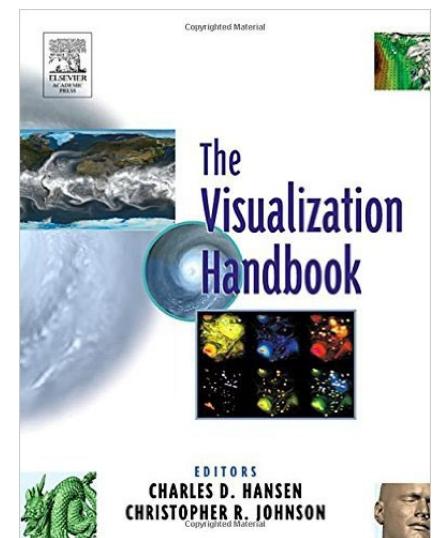
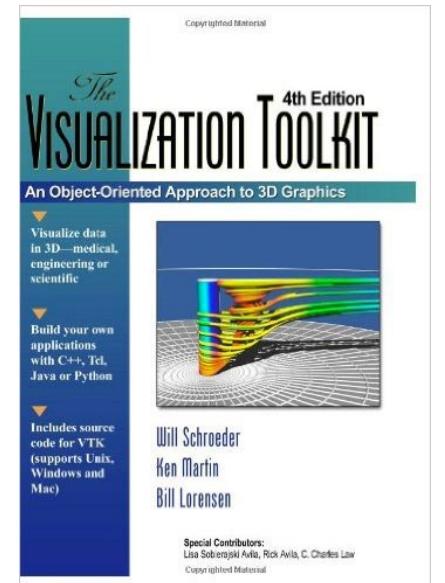
# Prerequisites

- Computer graphics
  - There will be an introduction to basic concepts (CG Primer)
- Mathematics
  - Vector calculus and linear algebra
  - Some differential-and integral calculus



# Organization

- Exercises
  - Practical implementation and application of rendering and visualization techniques in C++ using VTK
- Literature
  - "The Visualization Toolkit - An Object-Oriented Approach to 3D Graphics", Schröder, Martin, Lorensen (available online as PDF)
  - Focus on algorithms, not implementation
  - Software: <http://www.vtk.org>
- Further reading
  - “The Visualization Handbook”, C. D. Hansen, C. R. Johnson, Academic Press 2004



# Lecture contents

- Introduction
- Computer Graphics Primer
- Fundamental Concepts
- 1D and 2D scalar fields
- 3D scalar fields
- 2D and 3D vector fields

# 1. Introduction

# What is visualization?

- “to visualize” (Oxford English Dictionary)
  - Form a mental vision, image or picture of
    - something not visible,
    - or present to sight,
    - or of an abstraction
  - To make visible to the mind or imagination
    - e.g. air pressure
  - Transformation of an abstraction to a picture
    - e.g. molecular structure

"One picture is worth ten thousand words."

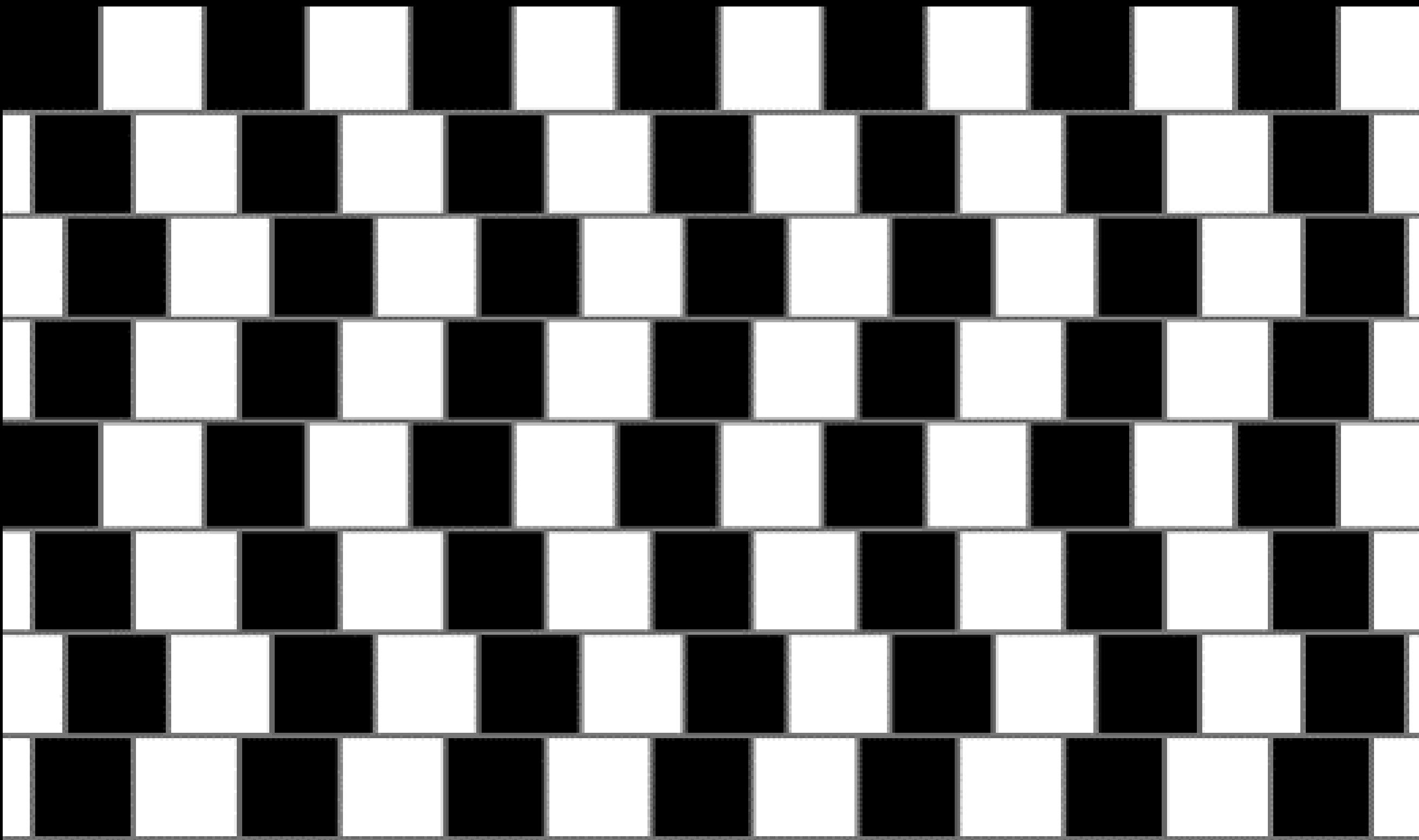
– Fred R. Barnard, Advertisement in *Printers' Ink*, 1921

"Denken ist interessanter als Wissen, aber nicht als Anschauen."

– Johann Wolfgang von Goethe, 1749 - 1832

# Importance of the Human Visual System





## Color Test

YELLOW

ORANGE

BLUE

BLACK

GREEN

RED

PURPLE

RED

YELLOW

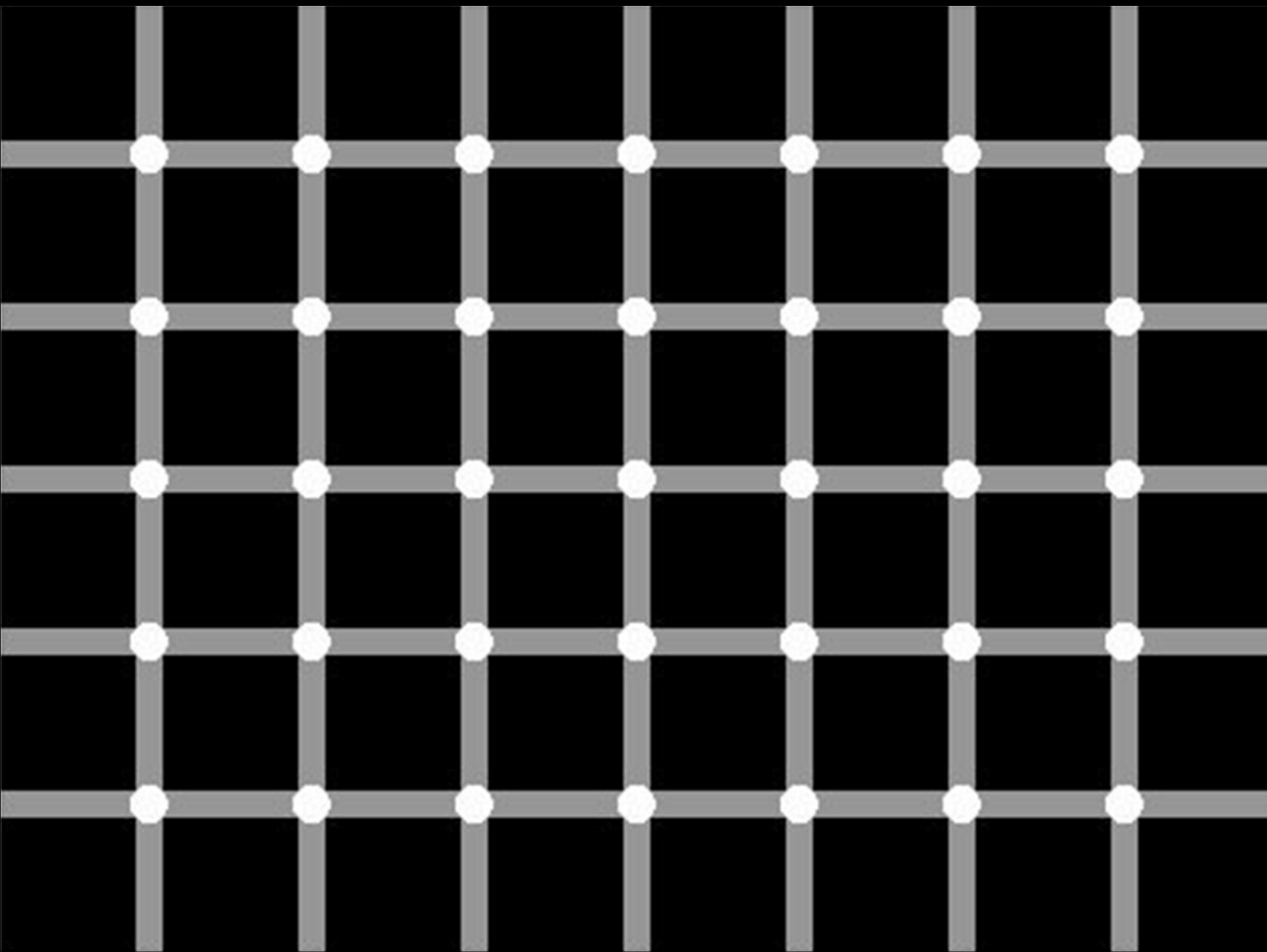
ORANGE

YELLOW

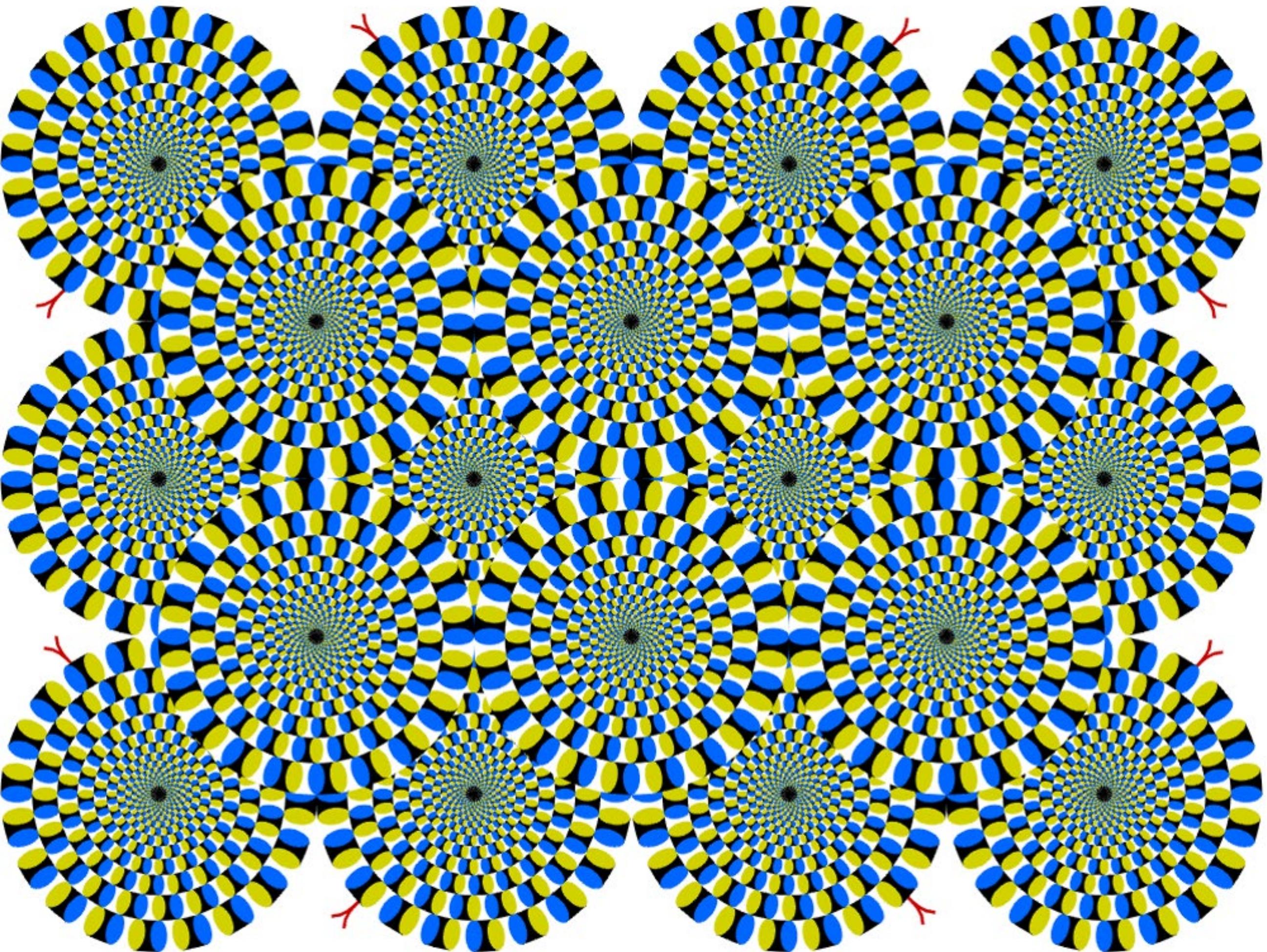
GREEN

### Left-Right Conflict

Your right brain tries to say the color, but your left  
brain insists on reading the word!



ohm



# About this Lecture

# Definitions

- Scientific Visualization
  - Visualization in scientific and technical environments
  - Computer aided extraction and display of information
    - from measured or simulated data
  - Not
    - Education
    - Marketing
    - Art
    - ...

# Definitions

"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."

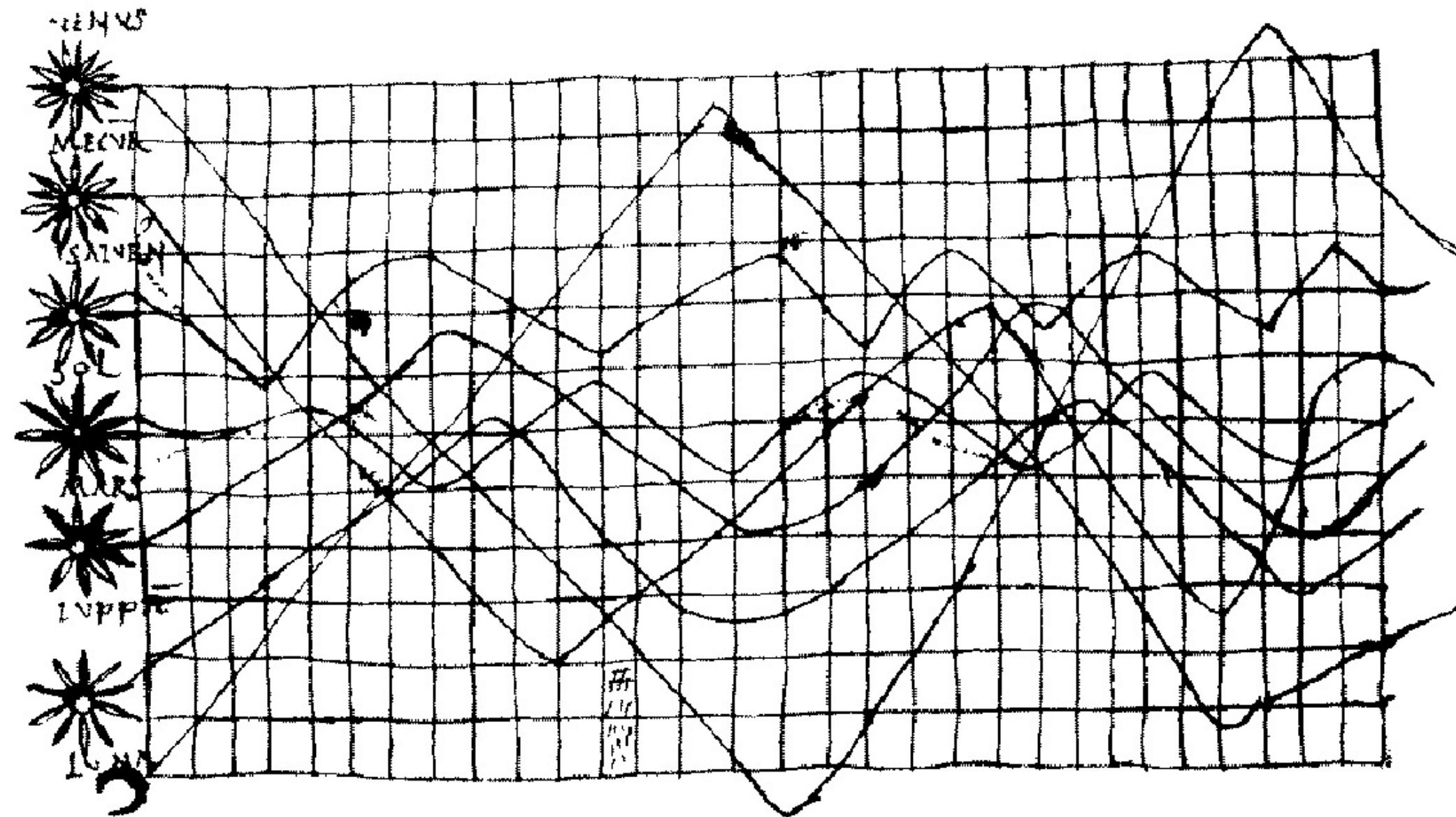
– McCormick, DeFanti, Brown, Visualization in Scientific Computing, Computer Graphics Vol. 21.6, Nov. 1987

# Definitions and goals

- Insight and analysis
  - Extract information content
  - Make coherences visible that are not apparent
  - Analyze data by means of visual representation
- Communication
  - Allow the non-expert to understand
  - Guide the expert into the right direction
- Steering
  - Interactively control and drive your application
  - Accelerate the understanding of phenomena

# Historic Examples

# History



Time series: inclination of planets

# History



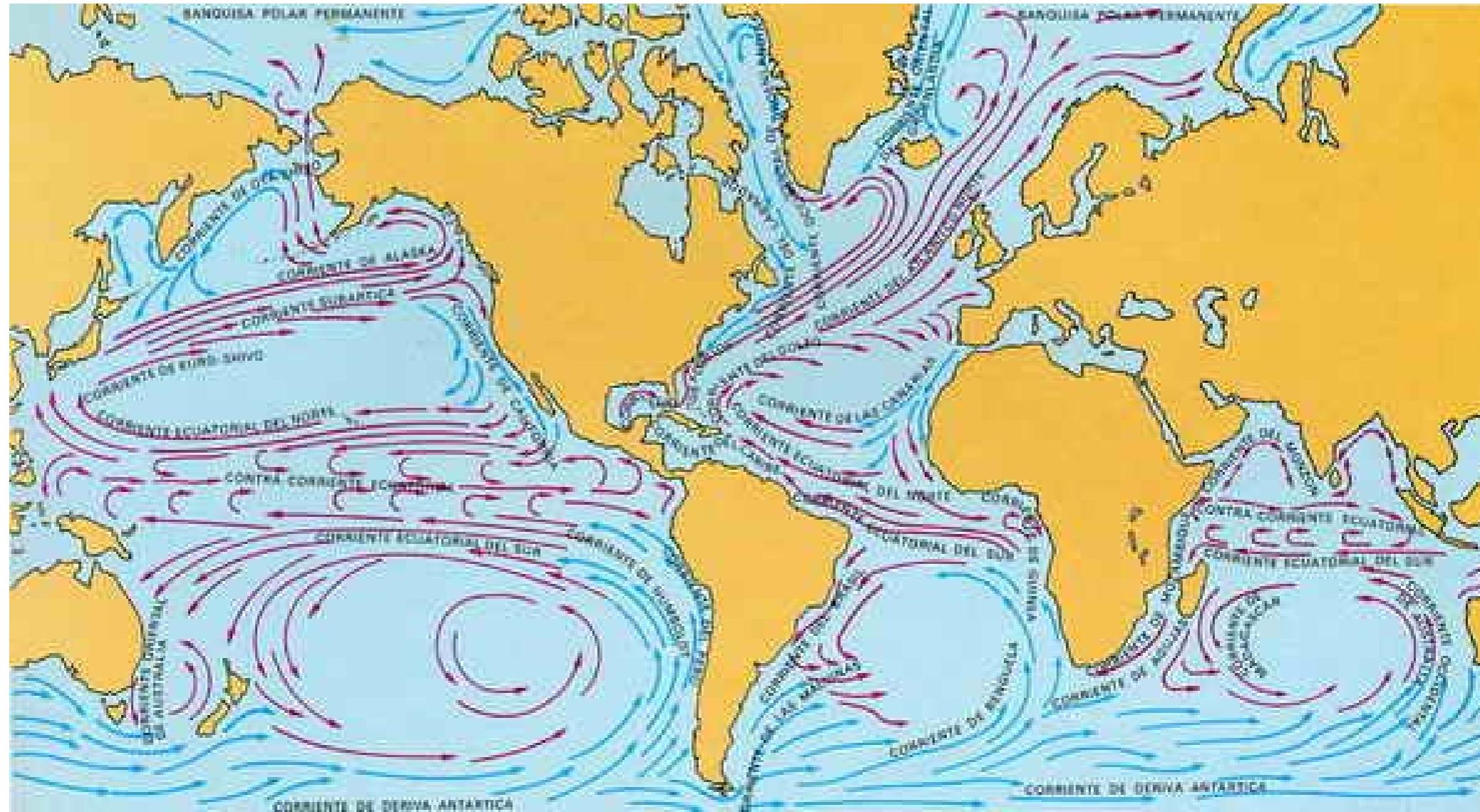
Ptolemaic map of the world by Johan Scotus (1505)  
based on the writings of Claudius Ptolemy (87 - 150 A.D.)

# History



Dr. John Snows map  
(1855) of death from  
cholera in the broad  
Street area  
September 1854.

# History



## Main ocean currents

Provides better understanding of transoceanic travel  
Courtesy of Albatros, Enciclopedia del mar, Barcelona 1974

# Interdisciplinarity

# Interdisciplinarity

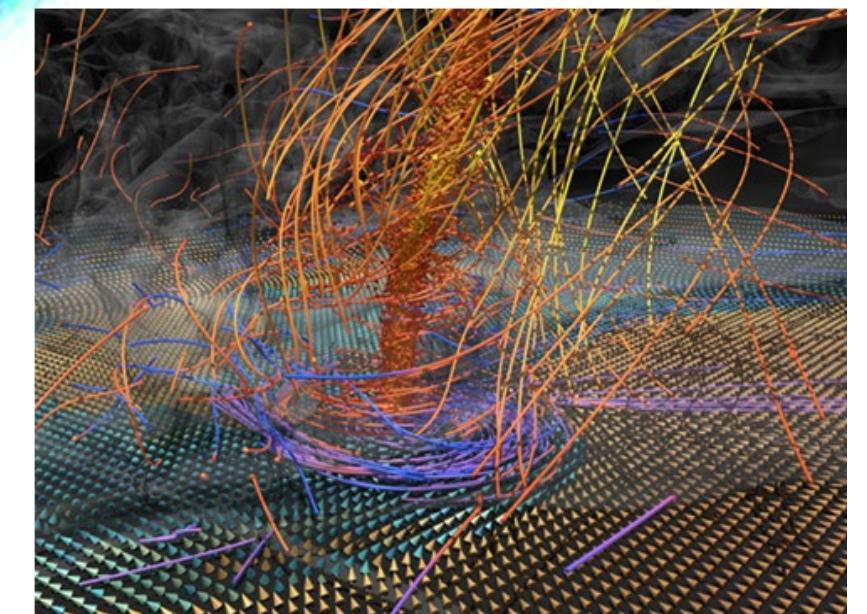
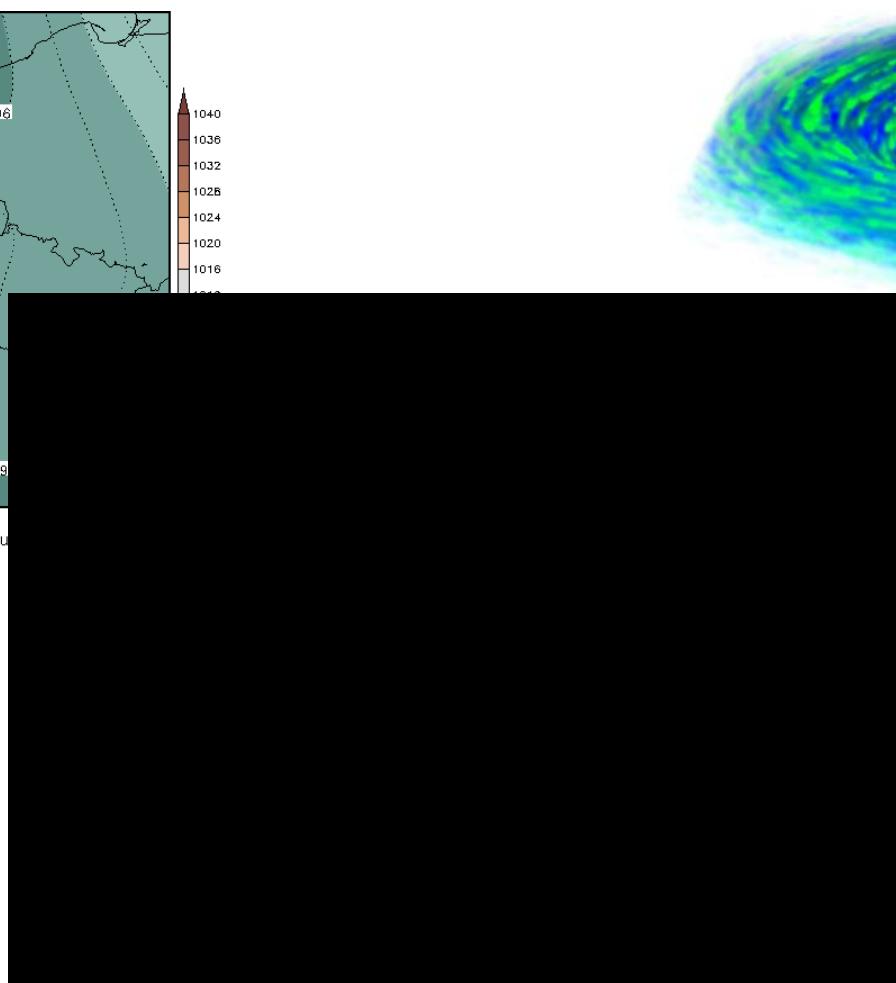
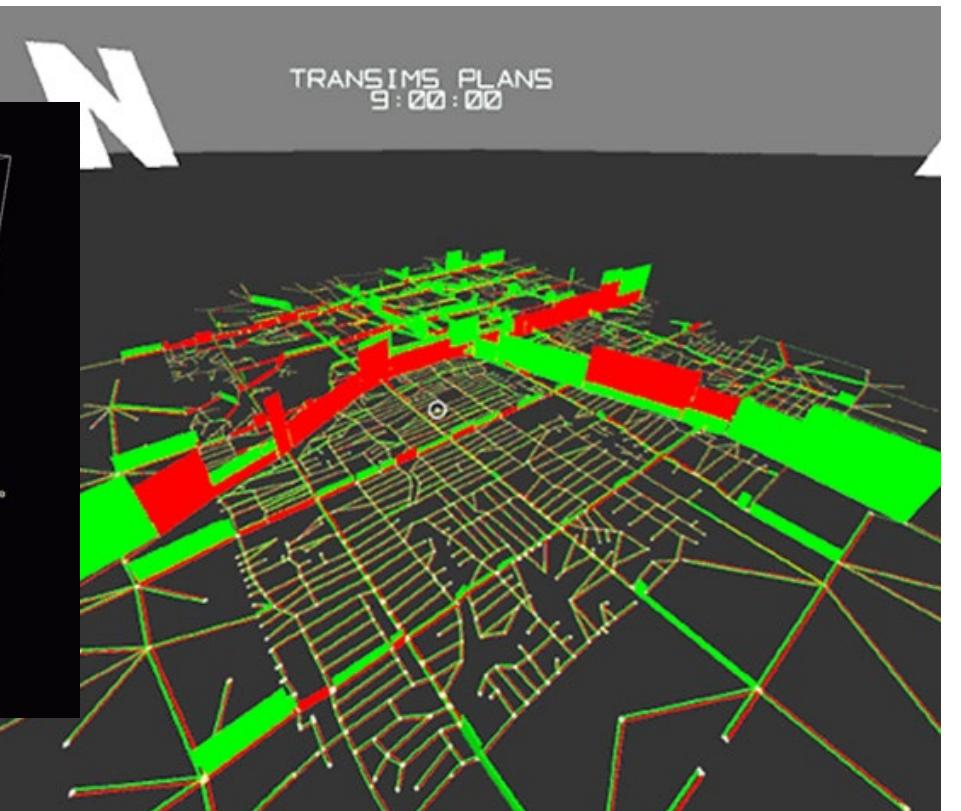
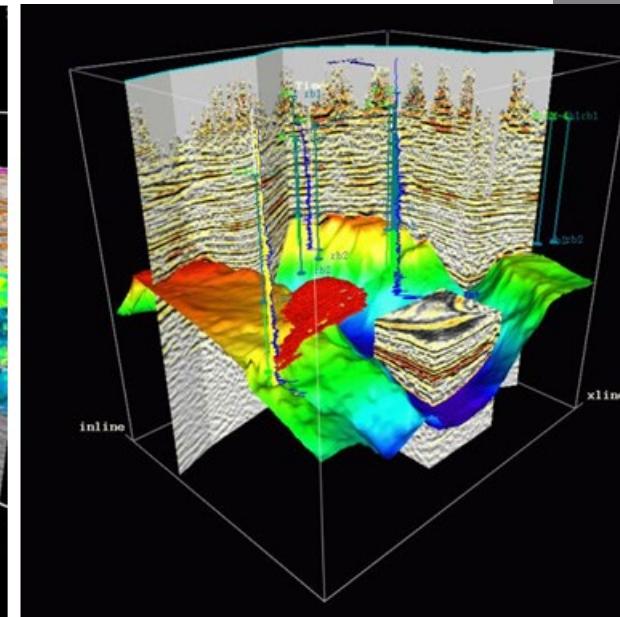
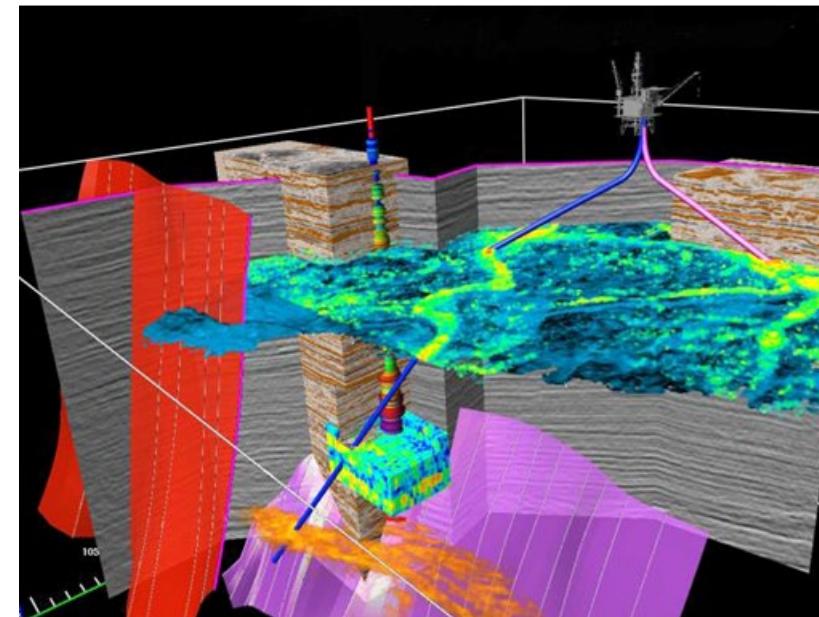
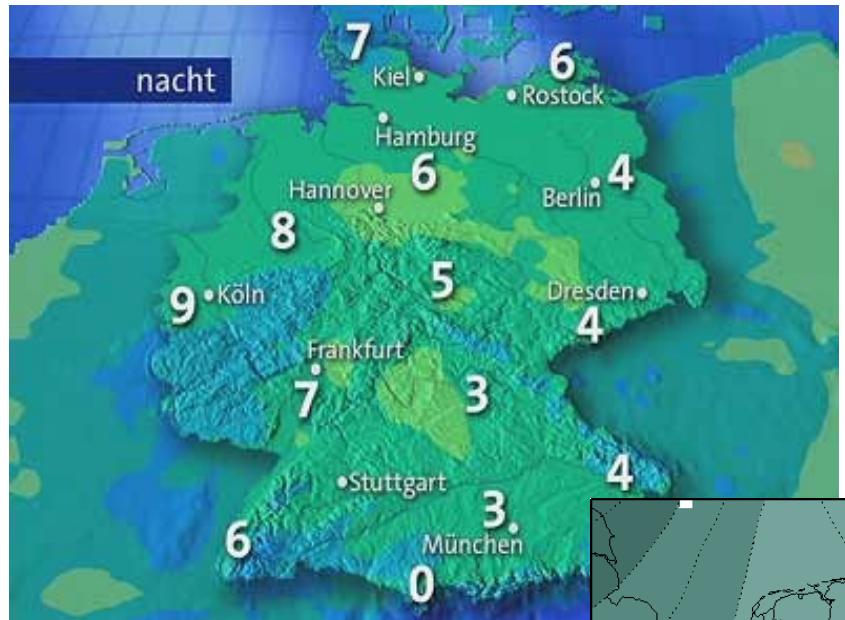
- Measurements and experiments
  - Medical imaging (e.g. computed tomography, ultrasound, ...)
  - Geology (e.g. oil exploration)
  - Meteorology and environment (e.g. weather, satellites)
  - Astronomy (e.g. digital radio telescope @300GB/s)
- Computer simulations
  - Computational fluid dynamics (CFD)
  - Structural mechanics
  - Chemistry (molecular modeling)
  - Physics (computational physics)

# Interdisciplinarity

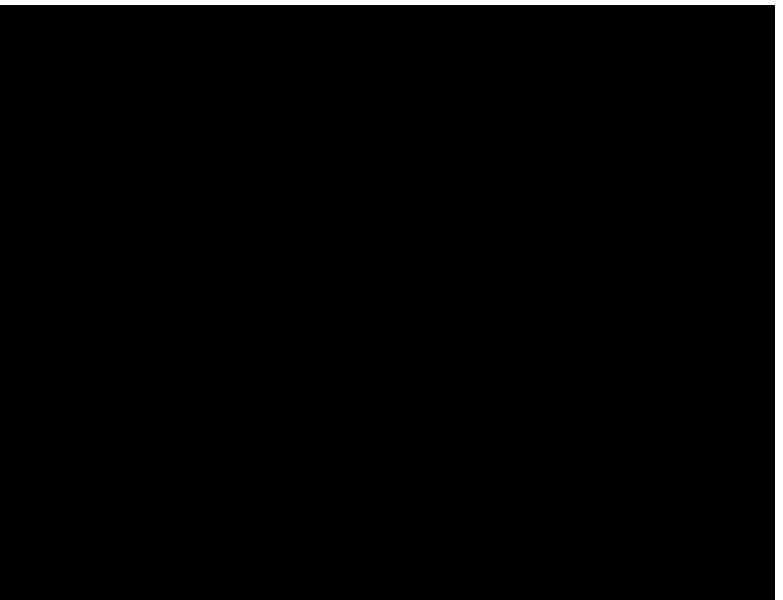
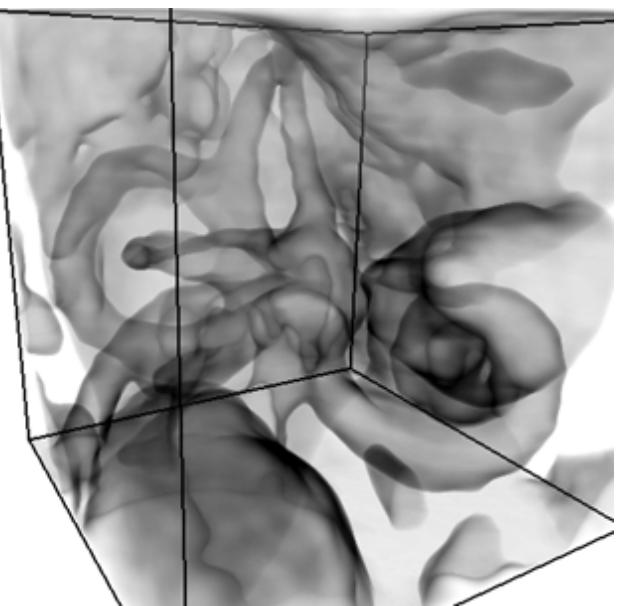
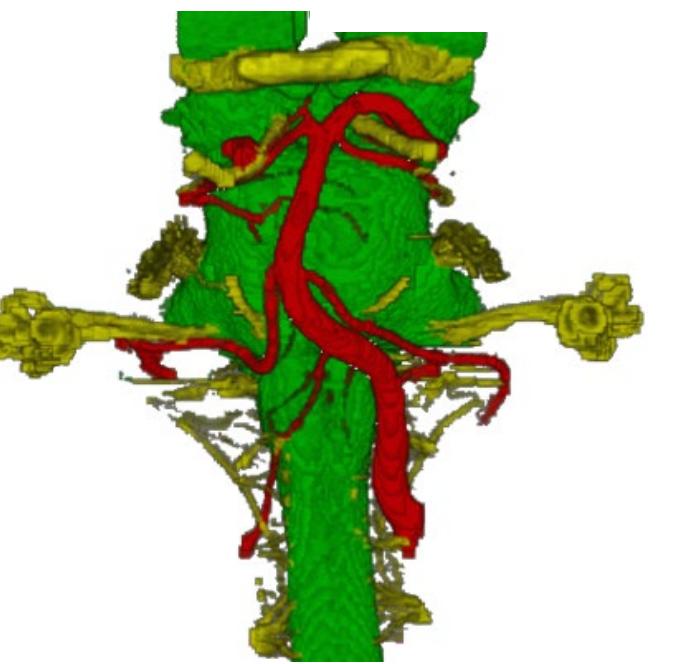
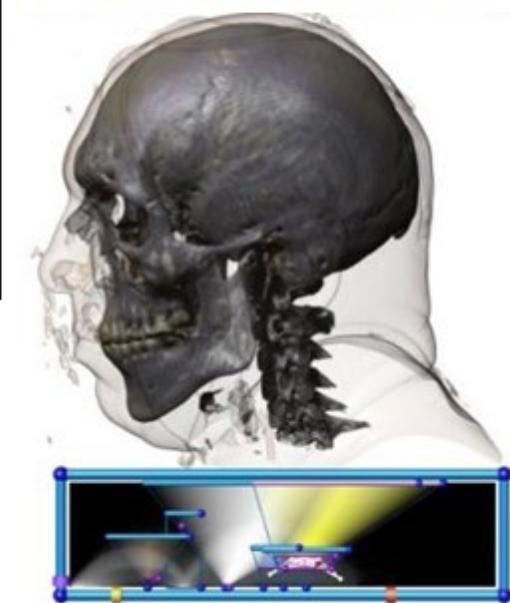
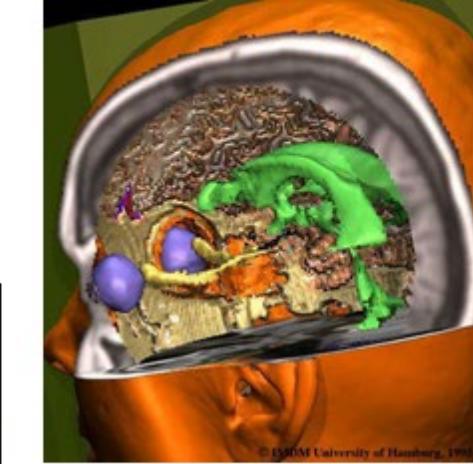
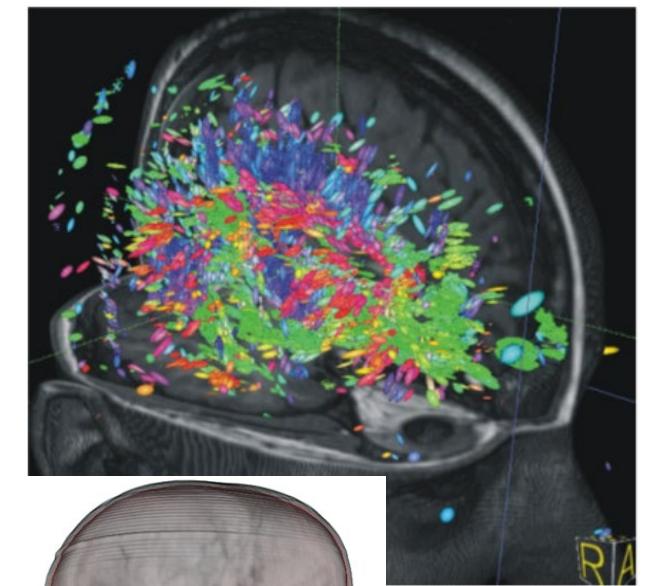
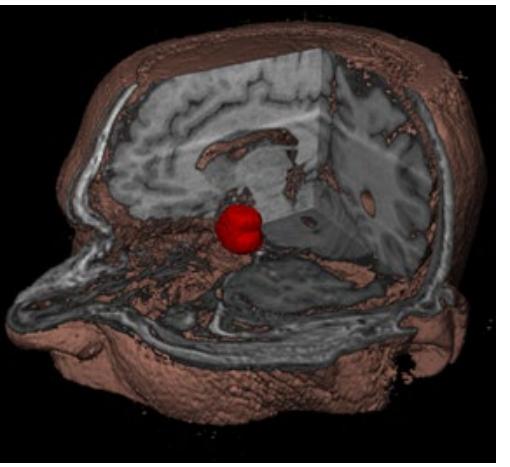
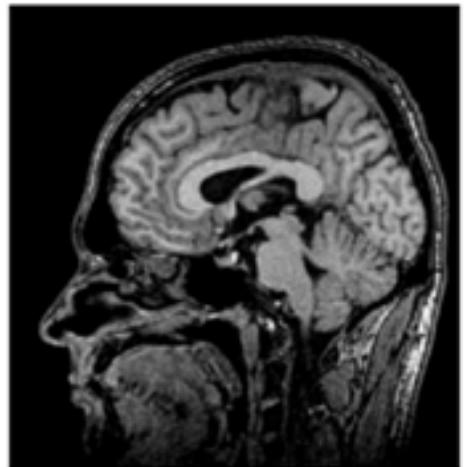
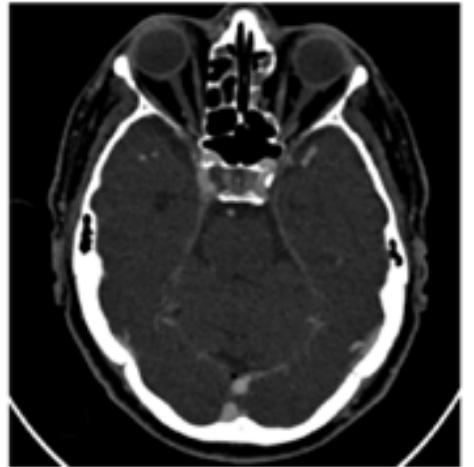
- Links with the following areas
  - Engineering
  - Numerical mathematics
  - Image processing
  - Computer vision
  - Physics
  - Chemistry
  - Medicine
  - Psychology
  - ...

# Examples

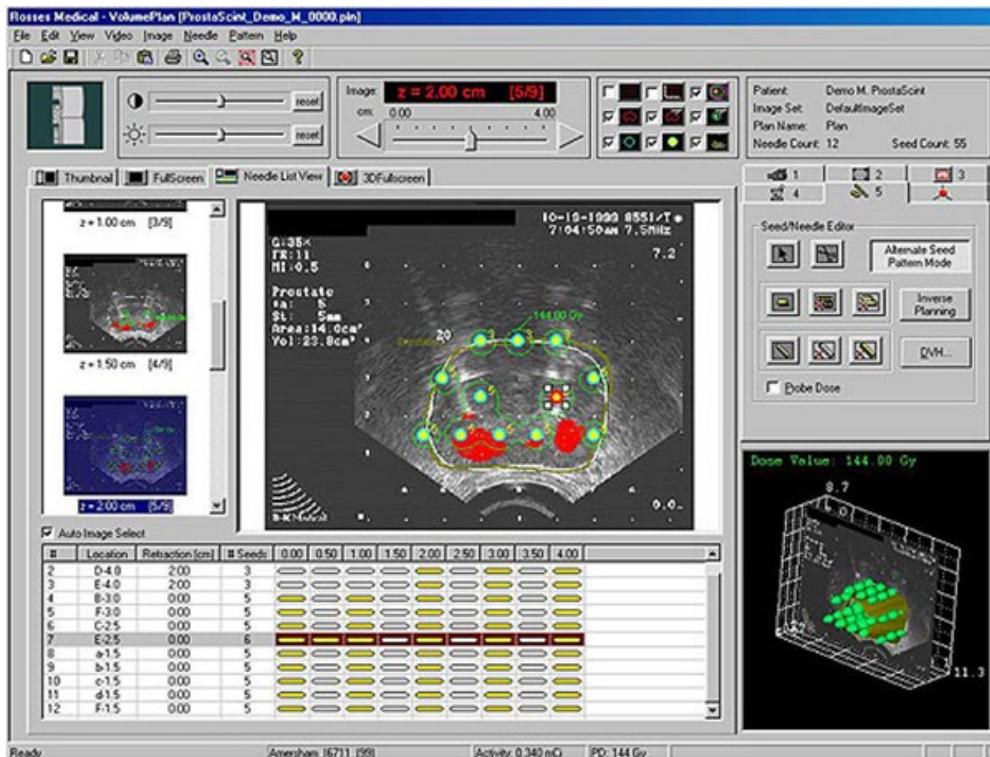
# Geosciences



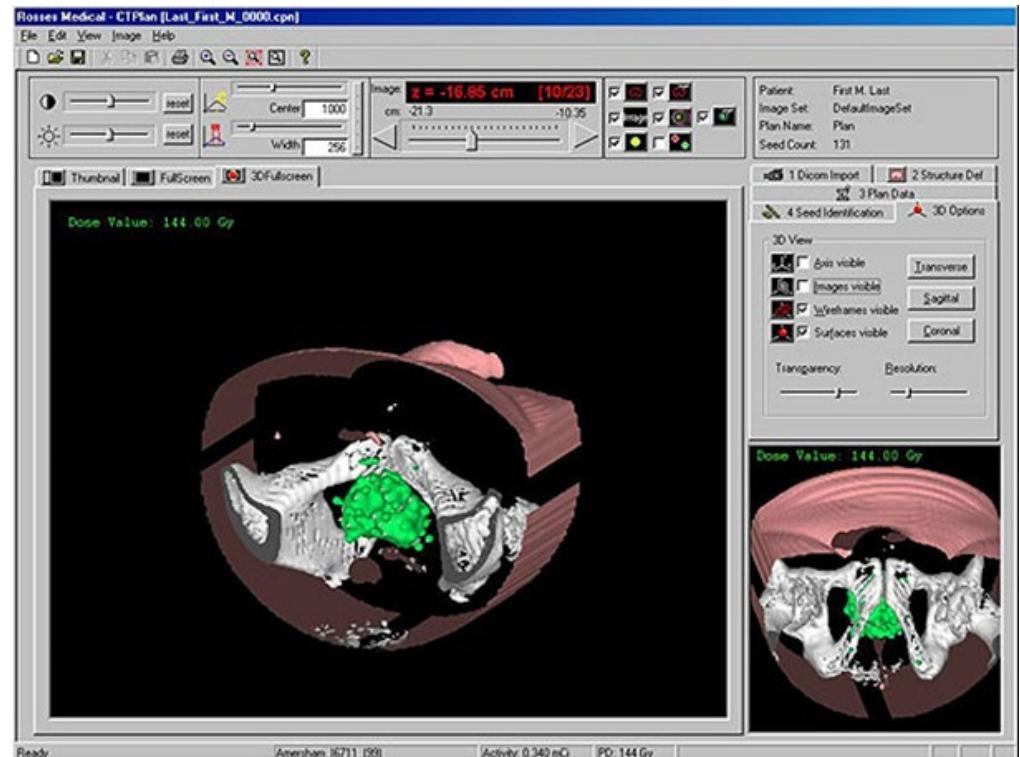
# Medicine



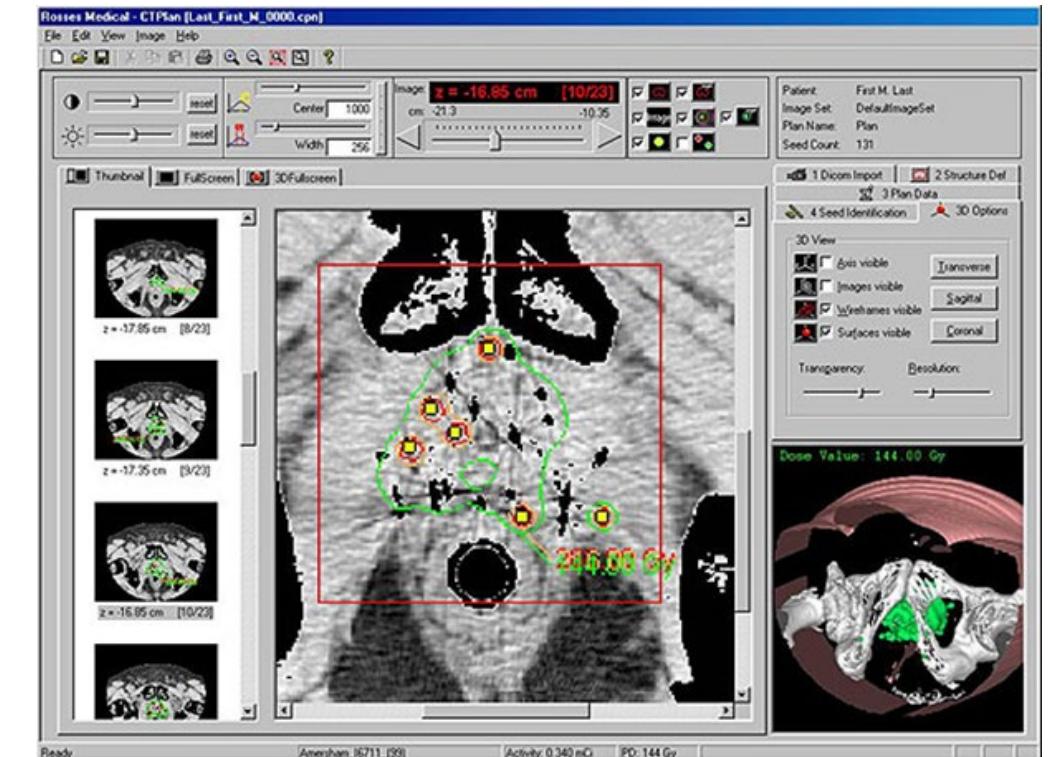
# Medicine



Diagnosis

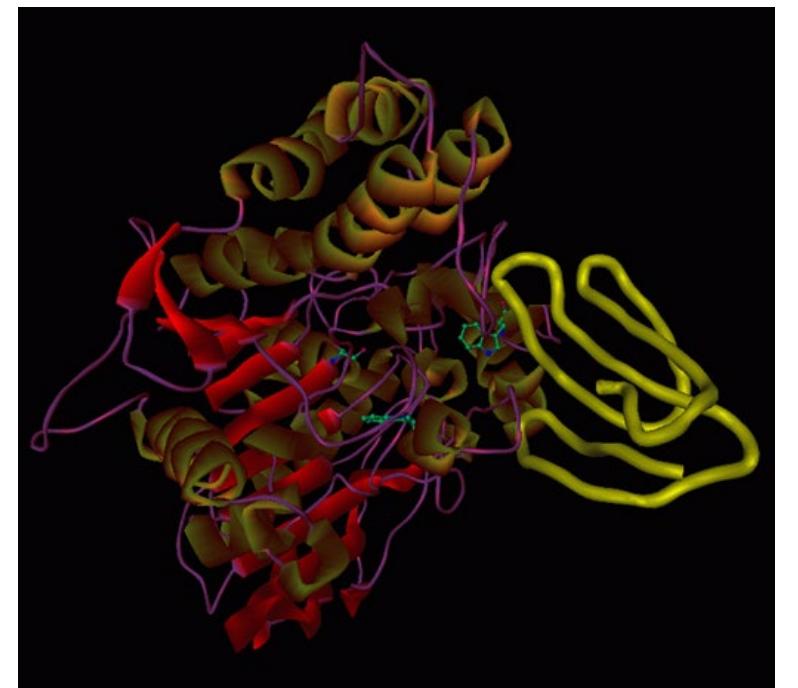
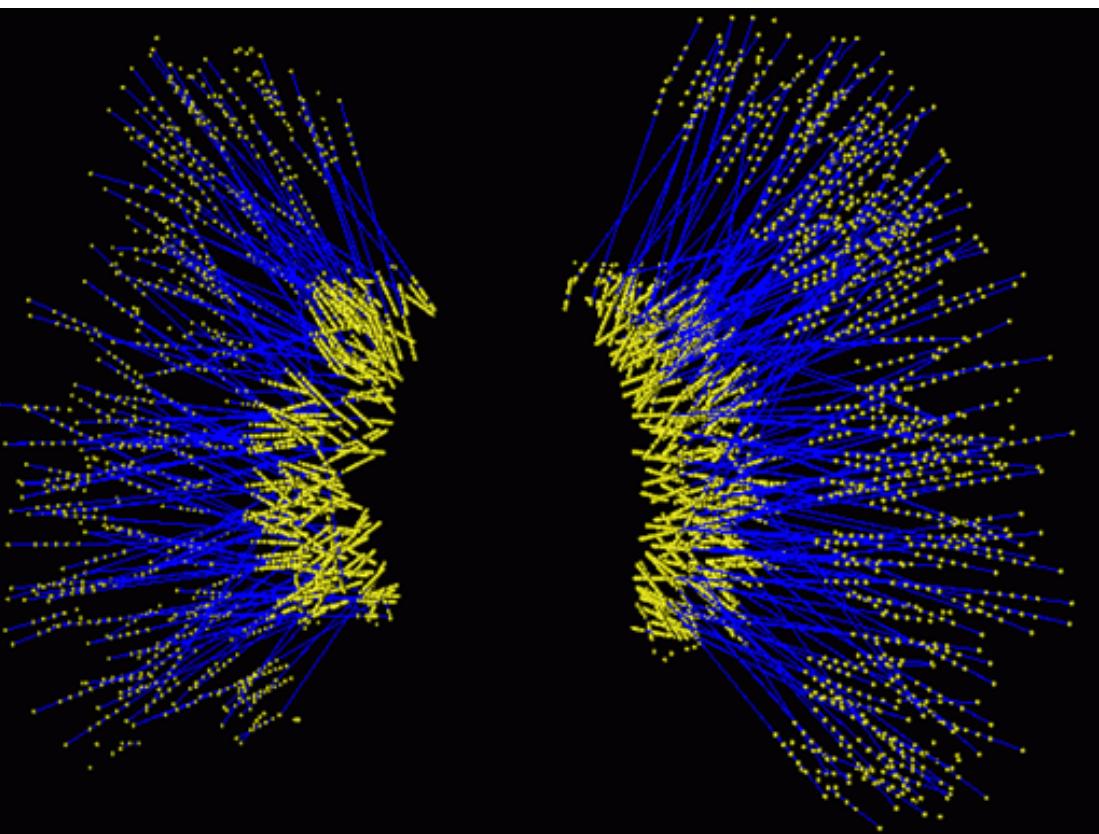
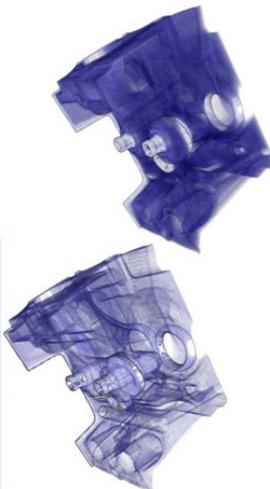
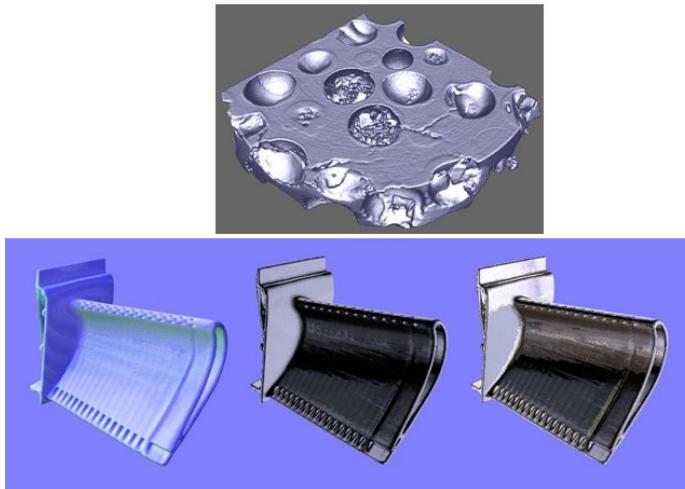


Therapy

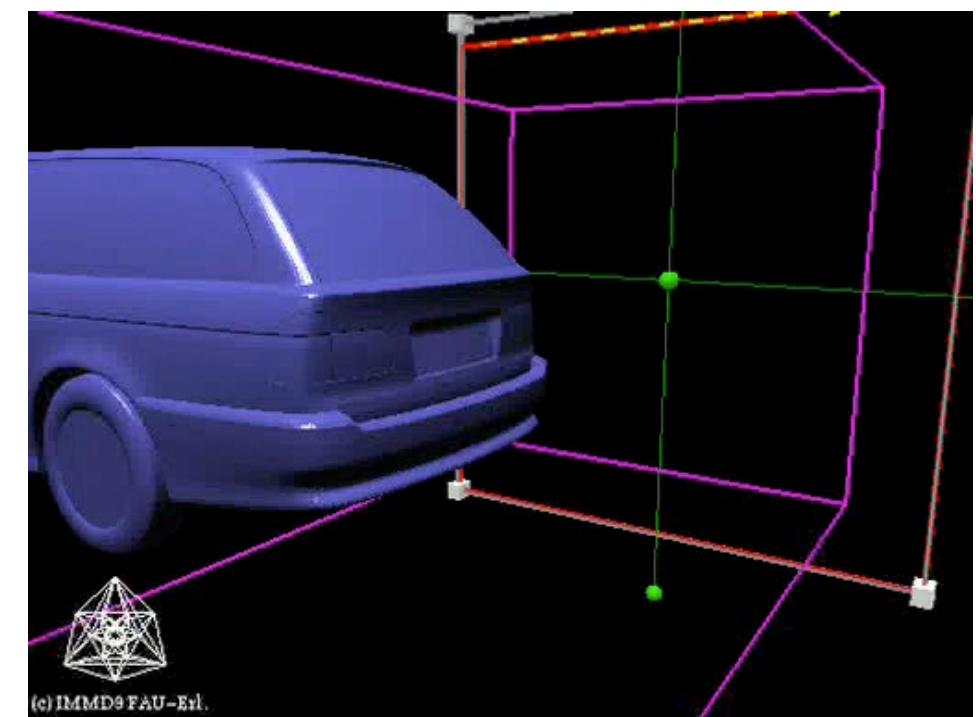
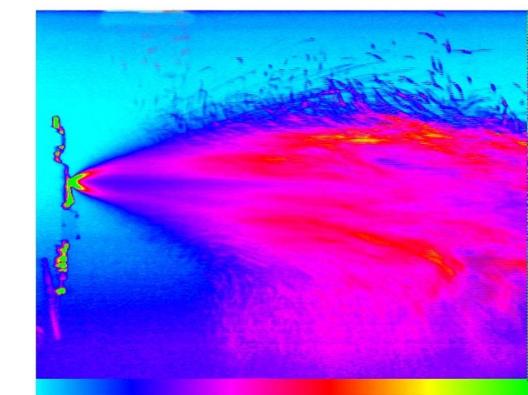
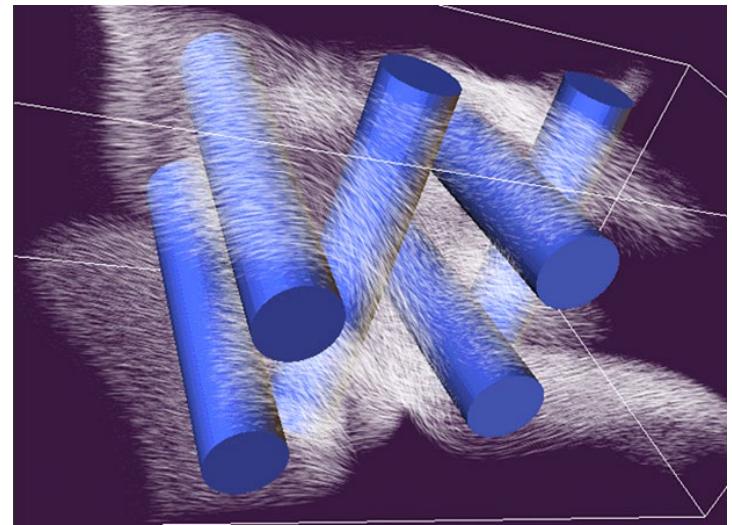
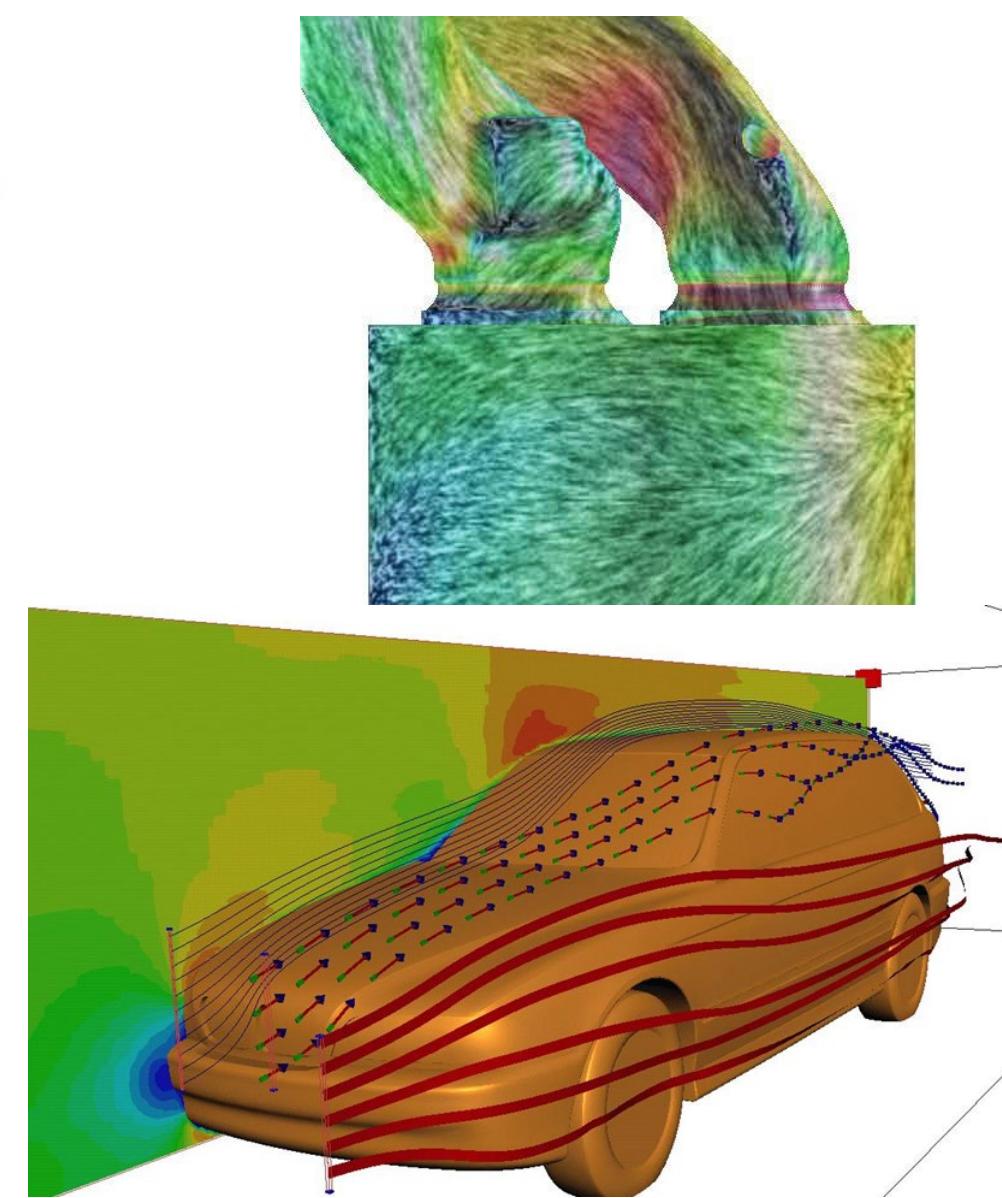
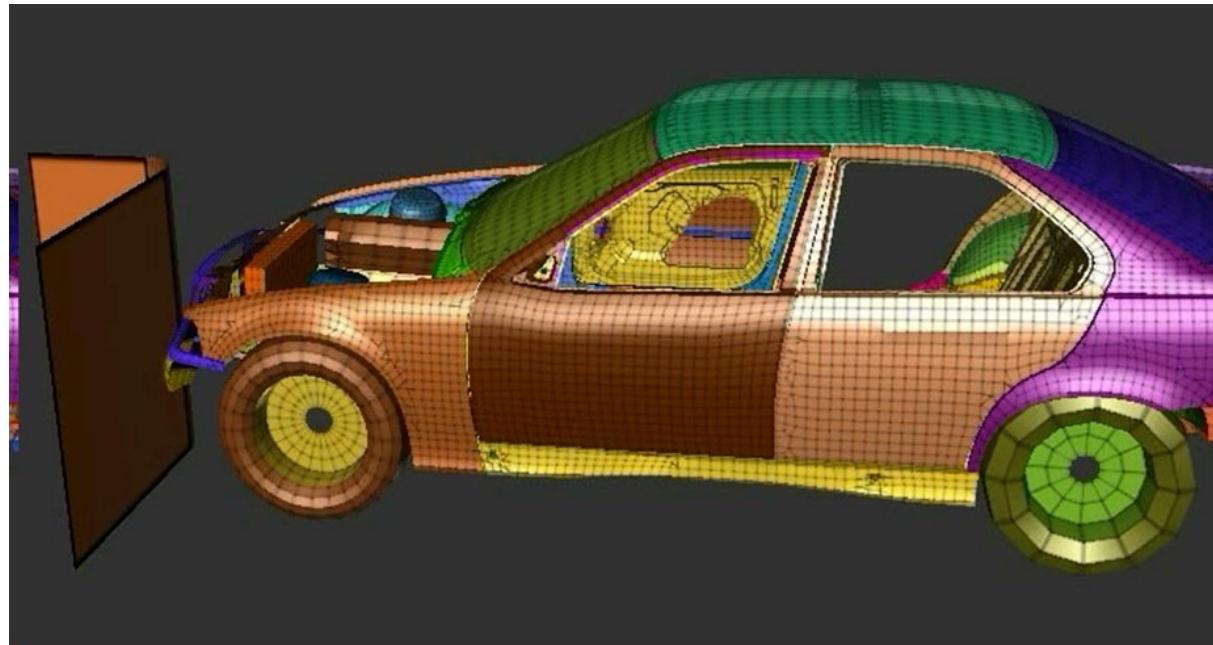
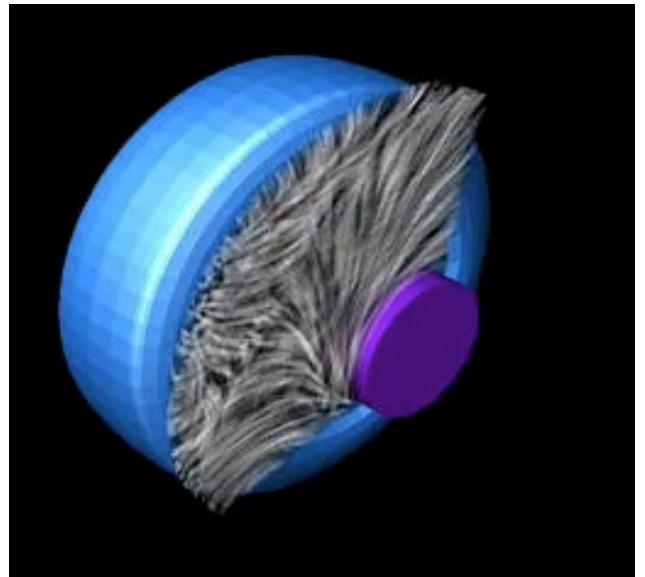
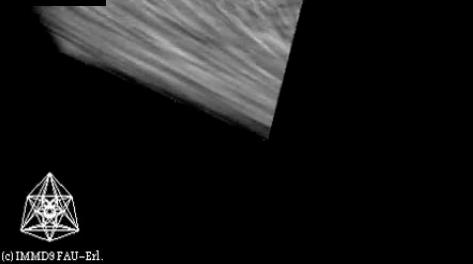
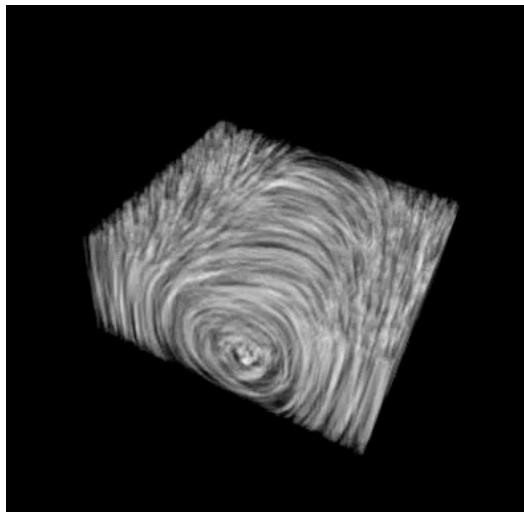
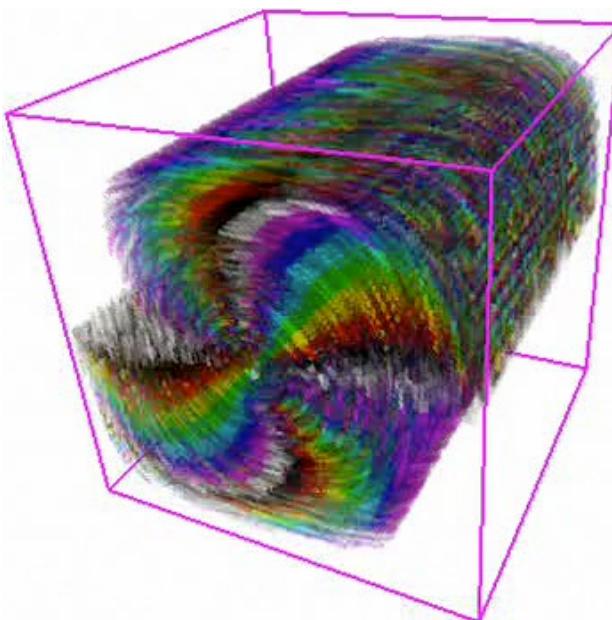


Follow up

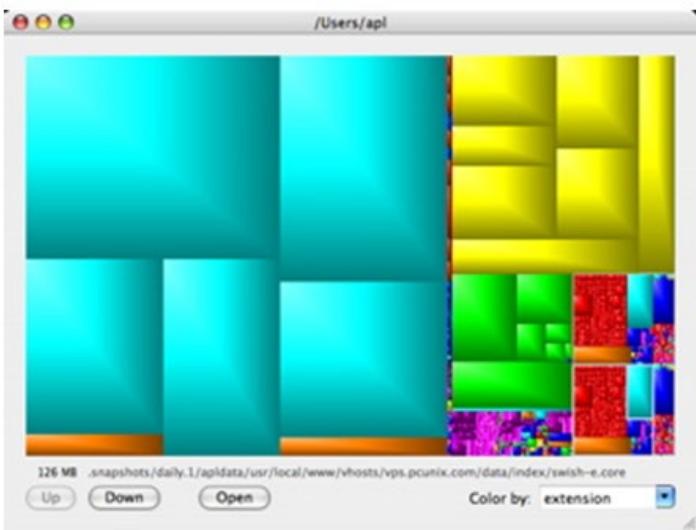
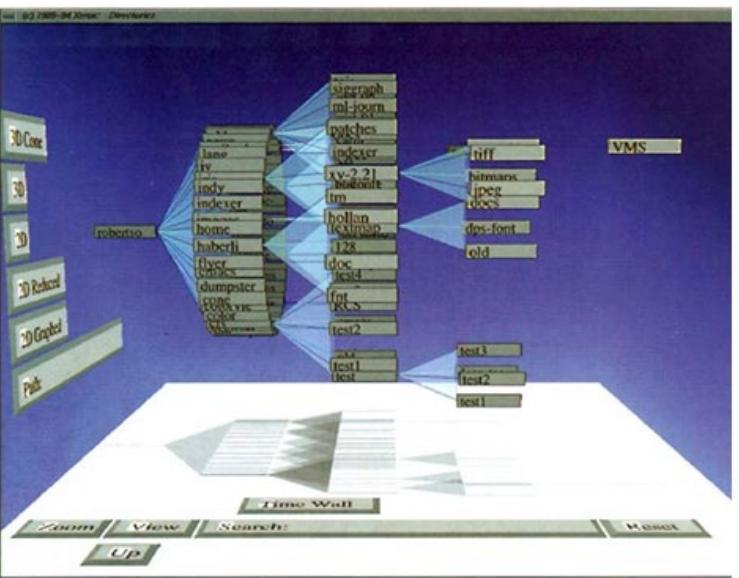
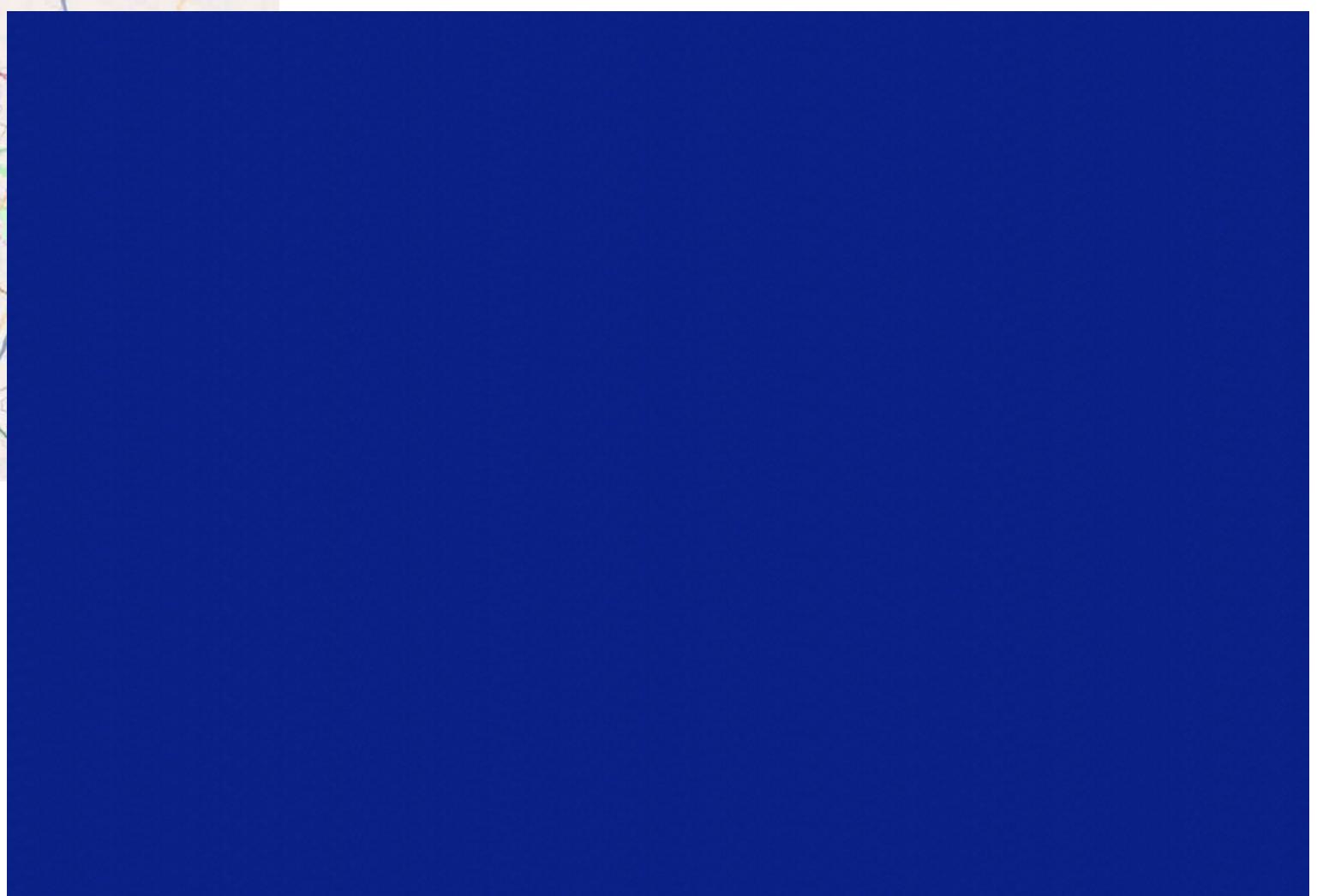
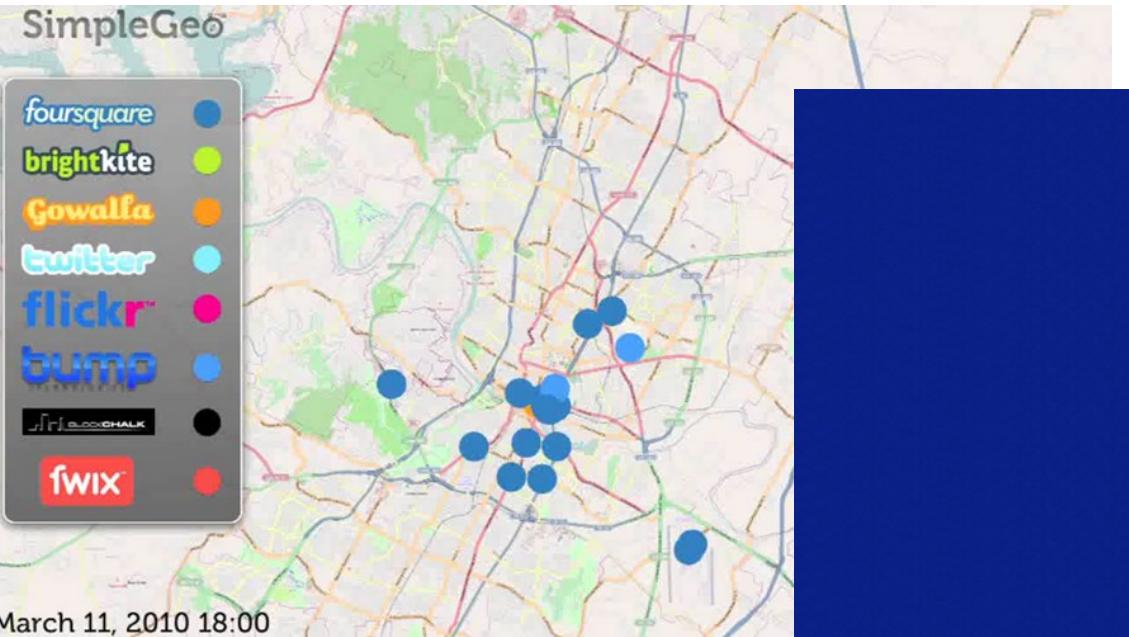
# Materials, Archeology, Chemistry, Physics, ...



# Engineering



# Information and Algorithms



# Related Fields

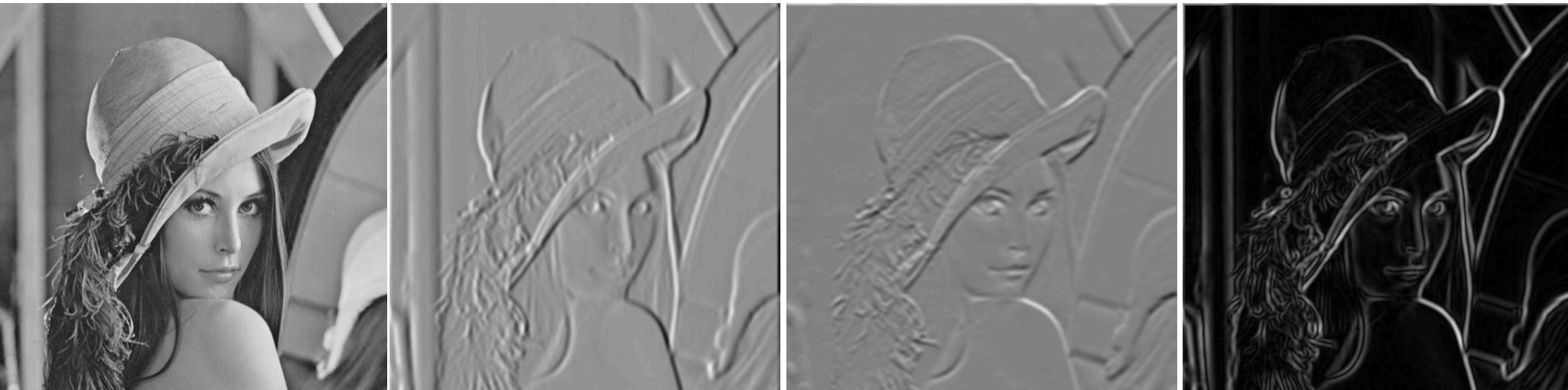
# Related Fields

## Image Synthesis and Geometric Modelling



# Related Fields

## Image Processing and Computer Vision



# Literature

# Books

- R. A. Earnshaw, N. Wiseman (Eds.), An Introductory Guide to Scientific Visualization, Springer, 1992
- K.W. Brodlie u.a. (Eds.), Scientific Visualization - Techniques and Applications, Springer 1992
- Richard S. Gallagher (Ed.), Computer Visualization: Graphics Techniques for Scientific and Engineering Analysis, CRC Press, 1995
- G.M. Nielson, H. Hagen, H. Müller, Scientific Visualization, IEEE Computer Society Press, Los Alamitos, 1997
- C.D. Hansen and C.R. Johnson, The Visualization Handbook, Academic Press, 2004
- C. Rezk-Salama, K. Engel, M. Hadwiger, J. Kniss, D. Weiskopf, Real-Time Volume Graphics, AK Peters, 2006
- W. Schroeder, K. Martin, B. Lorensen, Visualization Toolkit: An Object-Oriented Approach to 3D Graphics, 4th Edition, Kitware, 2006
- D. Weiskopf, GPU-Based Interactive Visualization Techniques, Springer; 2006
- B. Preim, D. Bartz, Visualization in Medicine. Theory, Algorithms, and Applications: Theory, Algorithms, and Applications, Morgan Kaufmann, 2007
- AC. Telea, Data Visualization: Principles and Practice, AK Peters, 2008
- Wolfgang Engel, GPU Pro: Advanced Rendering Techniques, A K Peters, 2010
- M. Ward, G.G. Grinstein, D. Keim, Interactive Data Visualization: Foundations, Techniques, and Applications, Taylor & Francis, 2010

## Journals and DL

- Journals:
  - IEEE Transactions on Visualization and Computer Graphics
  - IEEE Computer Graphics & Applications
  - The Visual Computer (Springer)
  - Computers & Graphics (Pergamon)
  - Visualization and Computer Animation (Wiley)
- IEEE / ACM digital libraries
  - Full text access from computers within the university