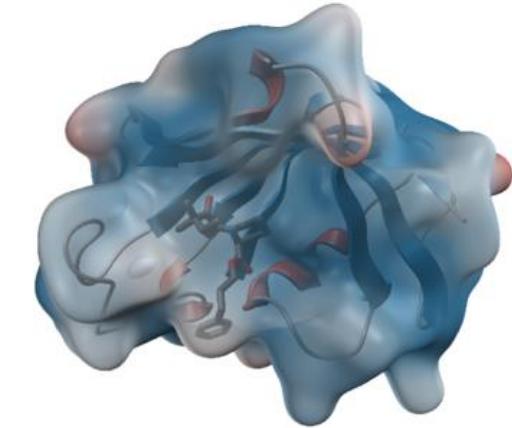




Scientific Visualization



Summer Semester 2021

Jun.-Prof. Dr. **Michael Krone**

Organization

- Lecturer
 - Jun.-Prof. Dr. Michael Krone (C104)
michael.krone@uni-tuebingen.de
- Tutors
 - Marco Schäfer, M.Sc. (C105)
marco.schaefer@uni-tuebingen.de
 - Marcel Bok, B.Sc.
marcel.bok@student.uni-tuebingen.de
- Course materials, assignments, announcements etc. via ILIAS
 - Course title:  **INF3145 - Scientific Visualization - Summer 2021**
 - ***Please check  ILIAS page/forum regularly for announcements!***
 -  Discord server for discussions with other students / instructors (see ILIAS)



Lecture & Tutorials

- Lecture

- Friday, 12:00-14:00 (c.t.) → *live Zoom video conference*
 - Lecture, Q&A, recap, discussion
- URL posted on ILIAS
- Slide video(s) each week (~Monday)



We recommend to install the free Zoom desktop client (see <https://zoom.us/>).

- Tutorials

- Live Zoom video conference, Friday, 14:00-16:00 (c.t.)
- **starts 30.04.2021!** (first exercise sheet next week)
- Short outline by **Marco** or **Marcel**, discussion of last week's exercise sheets
- *Time for questions (about exercises and lecture – in addition to lecture/discord!)*
- **No recording of exercise sessions!**

Exercises, Evaluation & Exam

- Exercises

- Weekly exercise sheets (theory + practical programming), hand in via ILIAS
- **You have to do the exercises in pairs!**

→ Web-based visualization in the browser

- Programming language: HTML, JavaScript, WebGL, maybe a little bit of Python

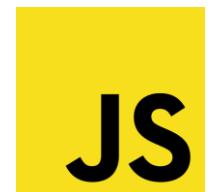
→ **No need for a fancy computer, any laptop should work!**

- Requirement to take exam:

- Pass exercises ($\geq 50\%$ of total points)
- *Possibility of bonus points for the exam if you do well*

- Final exam determines grade

- *Not yet determined whether it will be a written or oral exam*



Preliminary Schedule

- No lectures and tutorials on
 - May 28 (Pentecost week)
- Exercises:
 - First exercise sheet
 - Hand out: Thursday, April 29
 - Hand in: Thursday, May 6
 - Discussion: Friday, May 7
 - Second exercise sheet
 - Hand out: Thursday, May 6
 - Hand in: Thursday, May 13
 - Discussion: Friday, May 14
 - ...



Questions?

- During live lecture/tutorials on Friday
- ...or in the ILIAS course forum...
- ...or on discord...
- ...or via e-mail

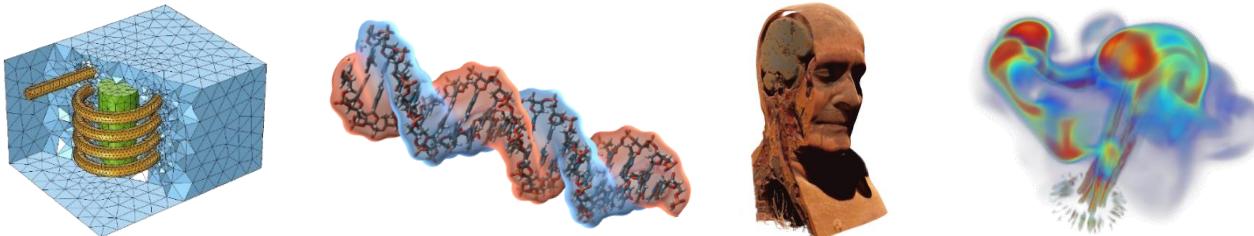


→ *Questions/discussions will not be part of the lecture videos!*

- **Please fill in the questionnaire on ILIAS!**
- You will need to do this in order to access the course materials

Lecture Content

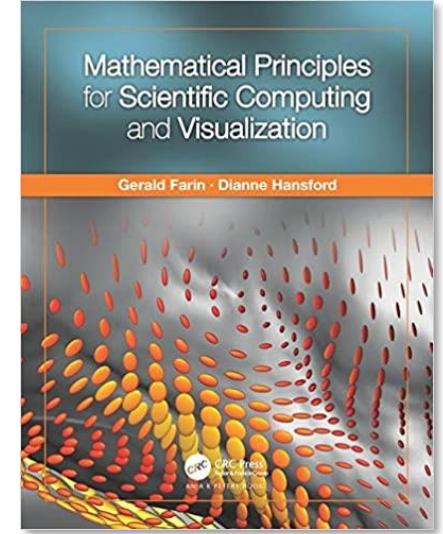
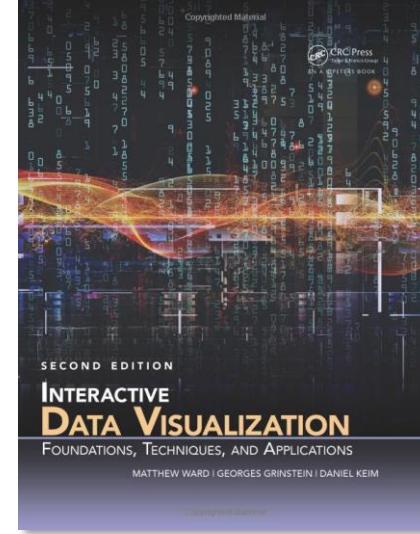
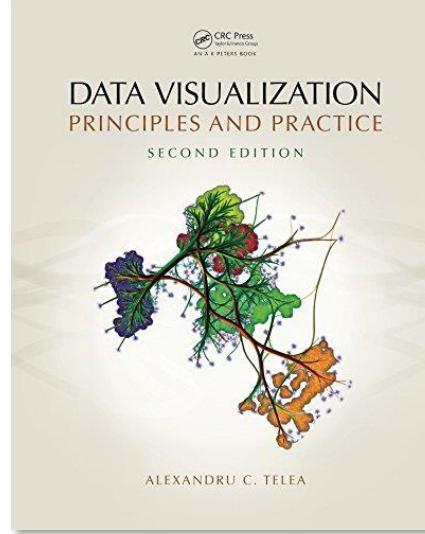
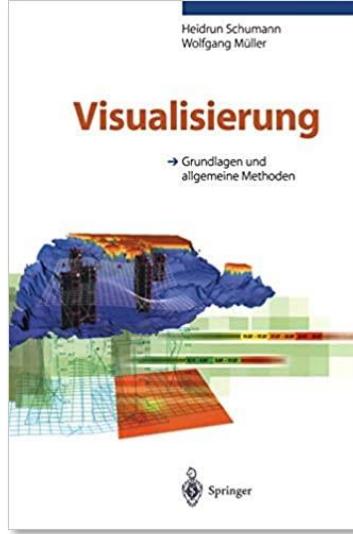
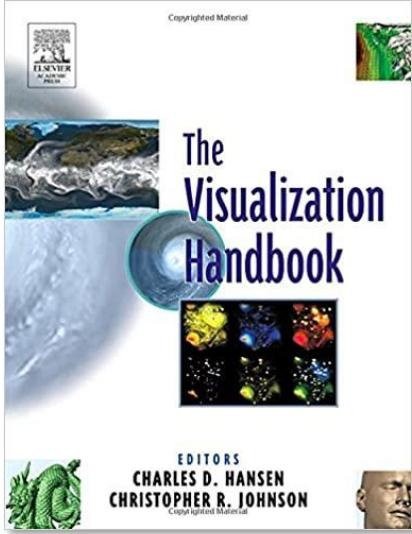
- What will you learn in this course?
 - Fundamentals of visualization of spatial data → **Scientific Visualization**
 - Data types & processing, visual mapping of data, visualization techniques,...
 - Practical applications and case studies
- *By the end of this lecture, you will be able to implement interactive (3D) visualizations for the most common scientific data sets!*



Content/slides partially based on previous lectures by

- Prof. Dr. Thomas Ertl / Prof. Dr. Daniel Weiskopf (University of Stuttgart)
- Prof. Dr. Andreas Butz (LMU Munich)

Literature – Books



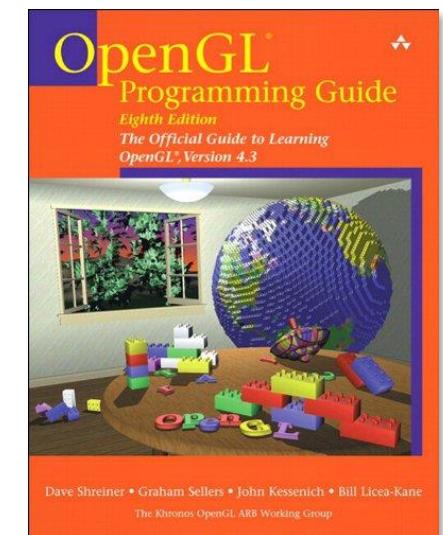
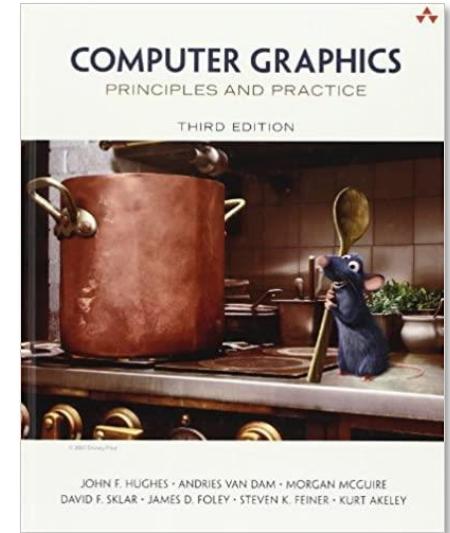
- C. D. Hansen, C. R. Johnson: "The Visualization Handbook"
- H. Schuhmann, W. Müller: "Visualisierung – Grundlagen und allgemeine Methoden"
- A. C. Telea: "Data Visualization – Principles and Practice"
- M. Ward, G. Grinstein, D. Keim: "Interactive Data Visualization"
- G. Farin, D. Hansford: "Mathematical Principles for Scientific Computing and Visualization"

Literature

- More books
 - Foley et al.: "Computer Graphics – Principles and Practice"
→ If you want to catch up on CG
 - Shreiner et al.: "OpenGL Programming Guide: The Official Guide to Learning OpenGL, Version 4.3"
→ If you want to learn more about OpenGL programming

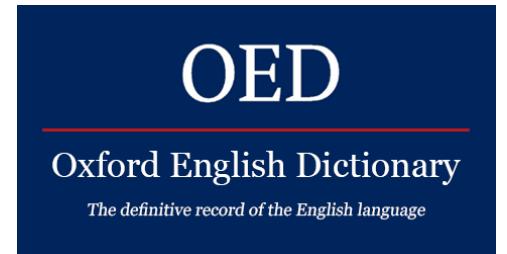
• Online resources

- Digital Libraries / journals / conference proceedings
 - Eurographics Digital Library (Comput. Graph. Forum)
 - IEEE Xplore Digital Library (IEEE TVCG)
- ...and – of course – Google (Scholar)



What is Visualization?

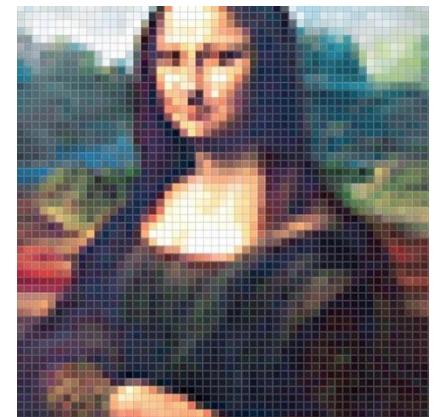
- Oxford English Dictionary



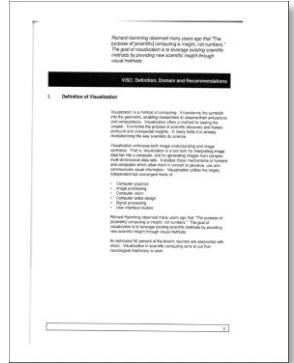
to visualize: To form a mental vision, image, or picture of (something not visible or present to the sight, or of an abstraction); to make visible to the mind or imagination.

→ Picture / image in the computer

- Color, patterns, objects,...
- Spatial resolution, temporal resolution ("moving picture", animation/movie), stereo,...



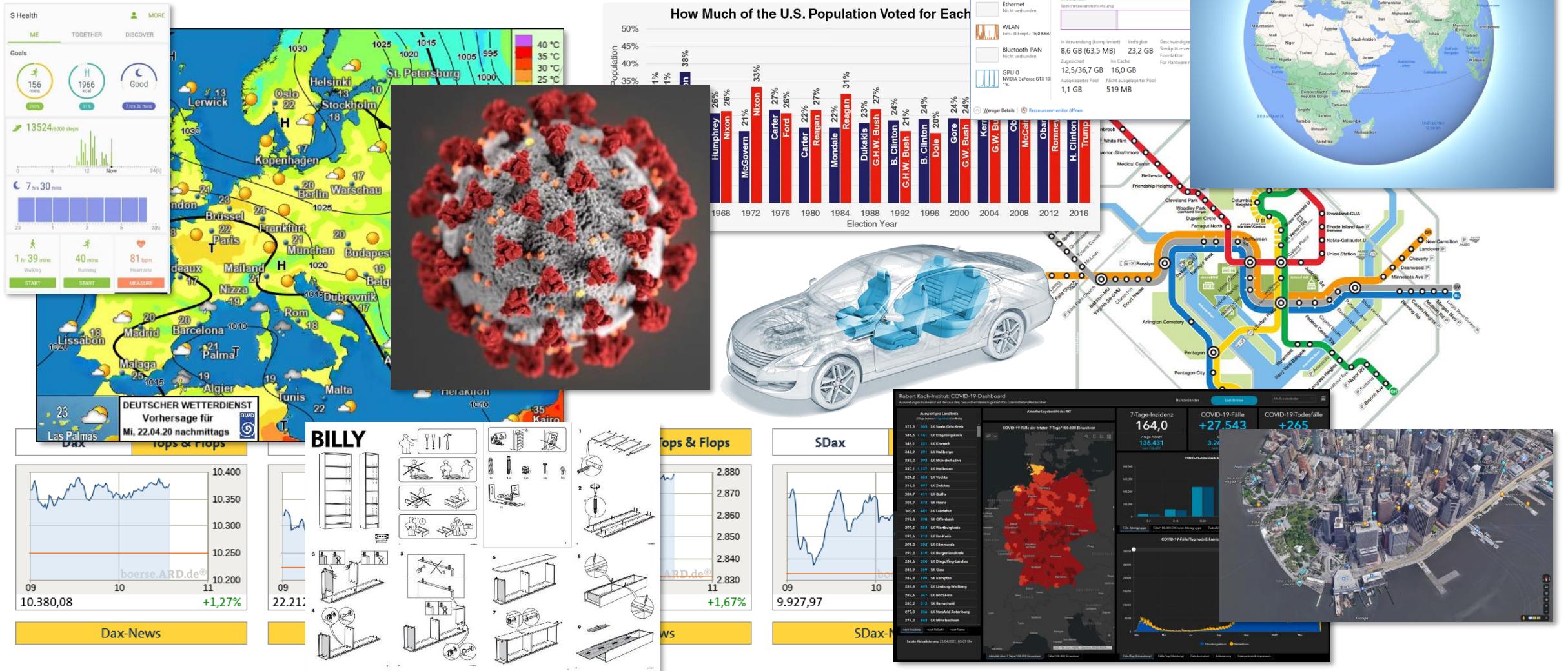
What is Visualization?



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.

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

Visualization is Everywhere!



Visualization Has a Long History!

- Visual representations have always been used to store/transfer data



Excavation



Reconstruction

Map of Çatal Hüyük (~6600 B.C.)

Probably the world's oldest cartographic map

Prehistoric cave paintings

(Sulawesi, Indonesia, ≥45 500 years ago)

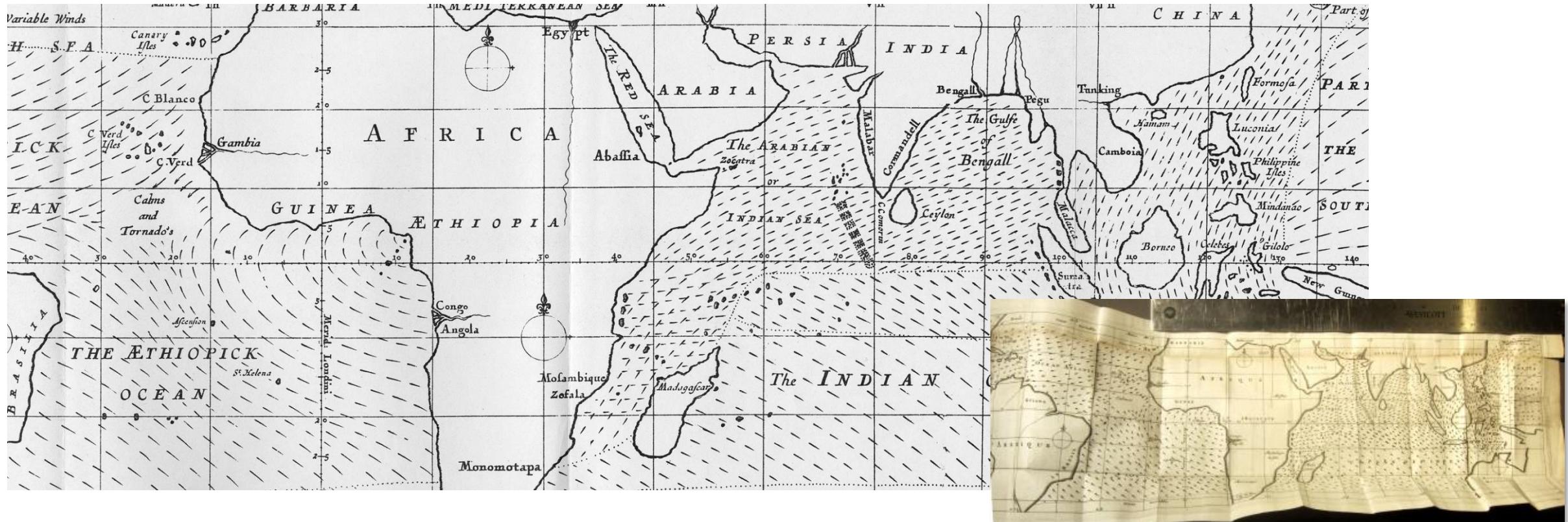


<https://advances.sciencemag.org/content/7/3/eabd648>



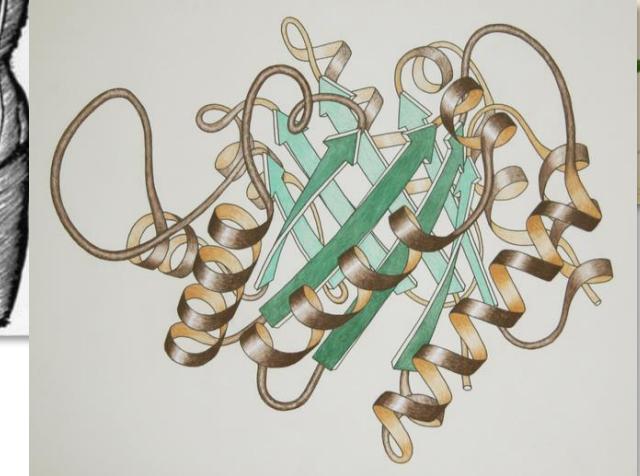
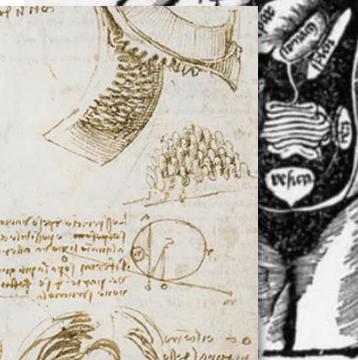
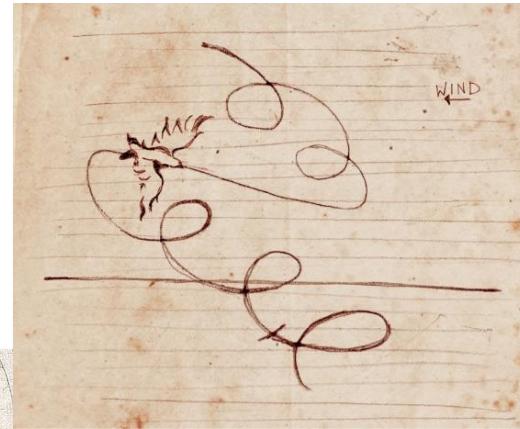
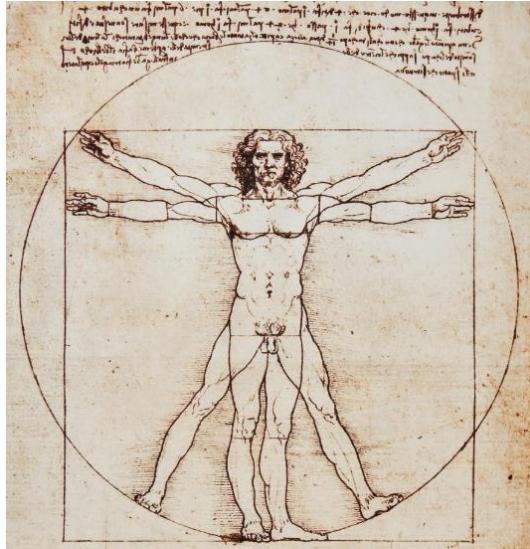
Visualization Has a Long History!

- Edmond Halley's map of the trade winds (1686)
 - Visualization of a vector field using streamlines



Visualization Has a Long History!

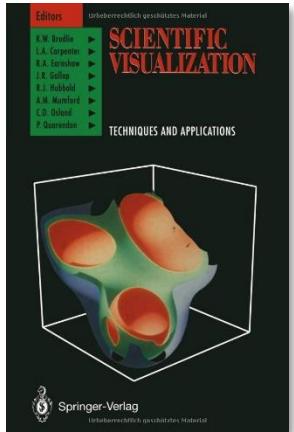
- Scientific illustrations (records of discoveries, medical research,...)



What is **Scientific** Visualization?

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, multi-dimensional data in such a way as to allow the user to extract significant features and results quickly and easily.

Brodlie, Carpenter, Earnshaw, Gallop, Hubbard, Mumford, Osland, Quarendon,
Scientific Visualization, Techniques and Applications, Springer-Verlag, 1992.

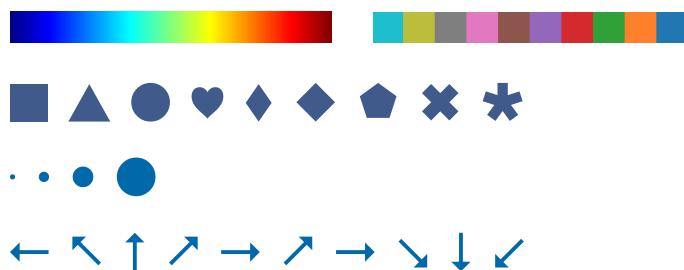
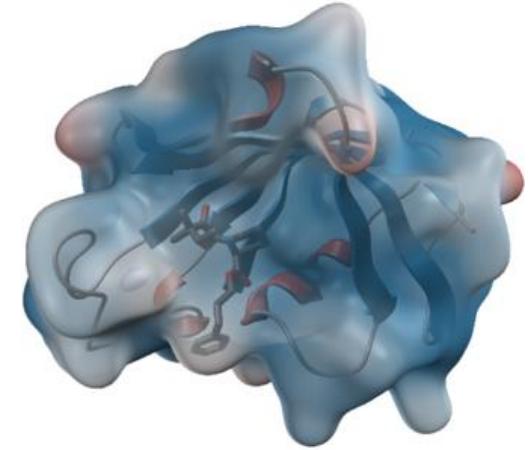


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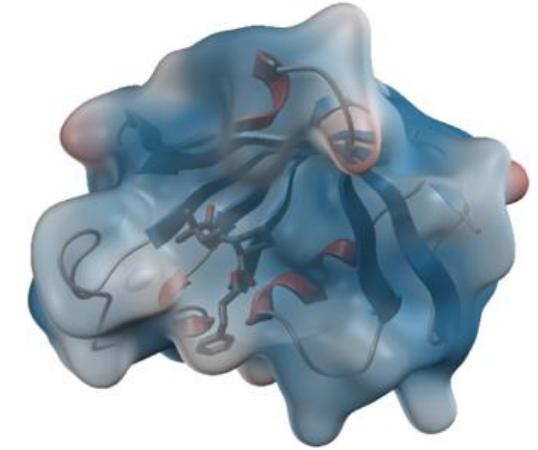
What is Scientific Visualization?

- Visualization of “scientific data”
- What is scientific data?
 - Data sets from simulations or physical measurements (quantitative data)
 - Inherent spatial reference (“spatial data”)
 - Limits the use of position channel in visual design
 - What visual channels do you know?
 - Color
 - Shape
 - Size
 - Orientation
 - ...



What is Scientific Visualization?

- Visualization of “scientific data”
- Problem:
 - Large data sets from analysis of processes and objects
 - Traditional presentation techniques insufficient
 - *“Looking at numbers”*
- Solution:
 - Generation of visual representations
= **(Scientific) Visualization**
 - Includes transformation of data and extraction of features
 - *“See the essential structure of the data”*



The power of the unaided mind is highly overrated...

The real powers come from devising external aids that enhance cognitive abilities.

Donald Norman



Visualization of Cardiac Blood Flow Using Anisotropic Ambient Occlusion for Lines

Benjamin Köhler¹, Matthias Grothoff², Matthias Gutberlet², Bernhard Preim¹

¹ Otto-von-Guericke University, Magdeburg, Germany

² Heart Center, Leipzig, Germany

Vision, Modeling, and Visualization (VMV) 2017



The interface includes a color wheel at the top right, a transfer function graph with a blue vertical bar and red points, and a histogram below it. On the right, there are buttons for 'Reset transfer function', 'Import transfer function', 'Export transfer function', and a dropdown for 'linear interpolation'. A checkbox for 'Show Histogram' is also present. The 'Properties' panel shows settings for a 'Directional light source' under 'Lighting Parameters', including 'Light Source Position' sliders (0,85, 0,27, 0,13), a 'Color' picker, a 'Light power (%)' slider (23,43), and an 'Enabled' checkbox. Another section for a 'Point light source' is partially visible.

Reset transfer function

Import transfer function

Export transfer function

linear interpolation

Show Histogram

Properties

Directional light source

Lighting Parameters

Light Source Position

Color

Light power (%)

Enabled

Point light source

Lighting Parameters

Here we interact with the upper body of a male

SCIVIS PAPER

Multi-Scale Procedural Animations of Microtubule Dynamics Based on Measured Data

Tobias Klein, Ivan Viola, Eduard Gröller, Peter Mindek



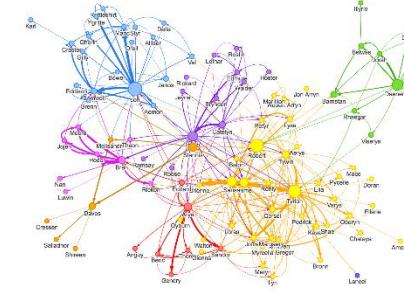
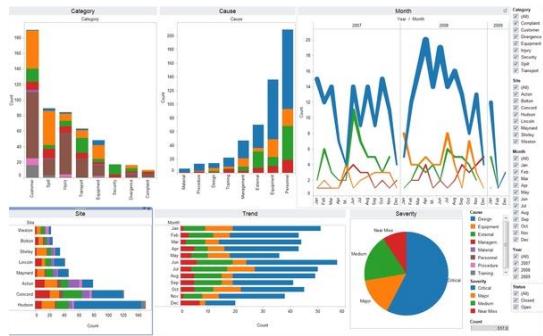
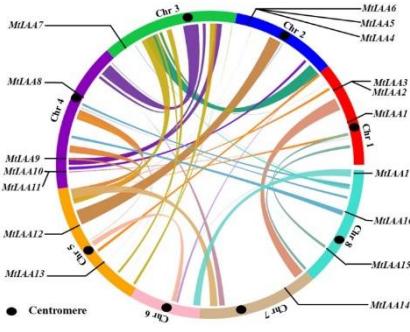
20-25 October 2019
Vancouver, Canada

ieeevis.org

What is **not** Scientific Visualization?

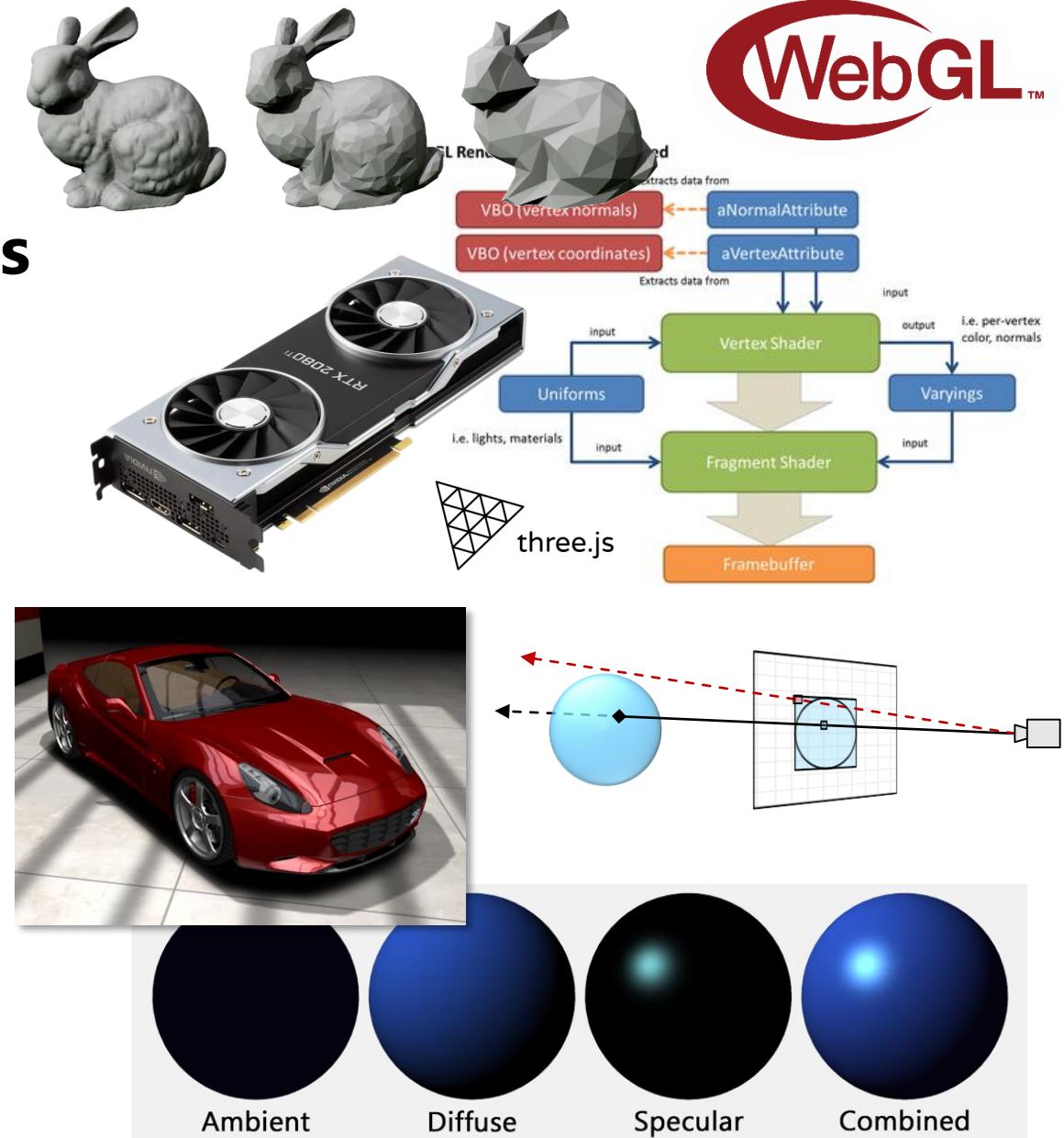
Information Visualization

- Abstract visualization of data that has no inherent spatial reference
 - Usually two-dimensional visualizations (plots, charts, graphs, etc.)
 - “Visualization of Biological Data” (BIO4364)
 - Master-level lecture in winter semester
 - Introduction to information visualization and Visual Analytics
(also possible for bachelor students, no biological knowledge required)



Lecture Content

- **Introduction to Computer Graphics**
- The Visualization Process
- Data Sources and Representations
- Filtering, Interpolation, and Mapping
- Particle Visualization
- Volume Visualization
- Vector and Tensor Field Visualization
- Interactive Visualization Systems

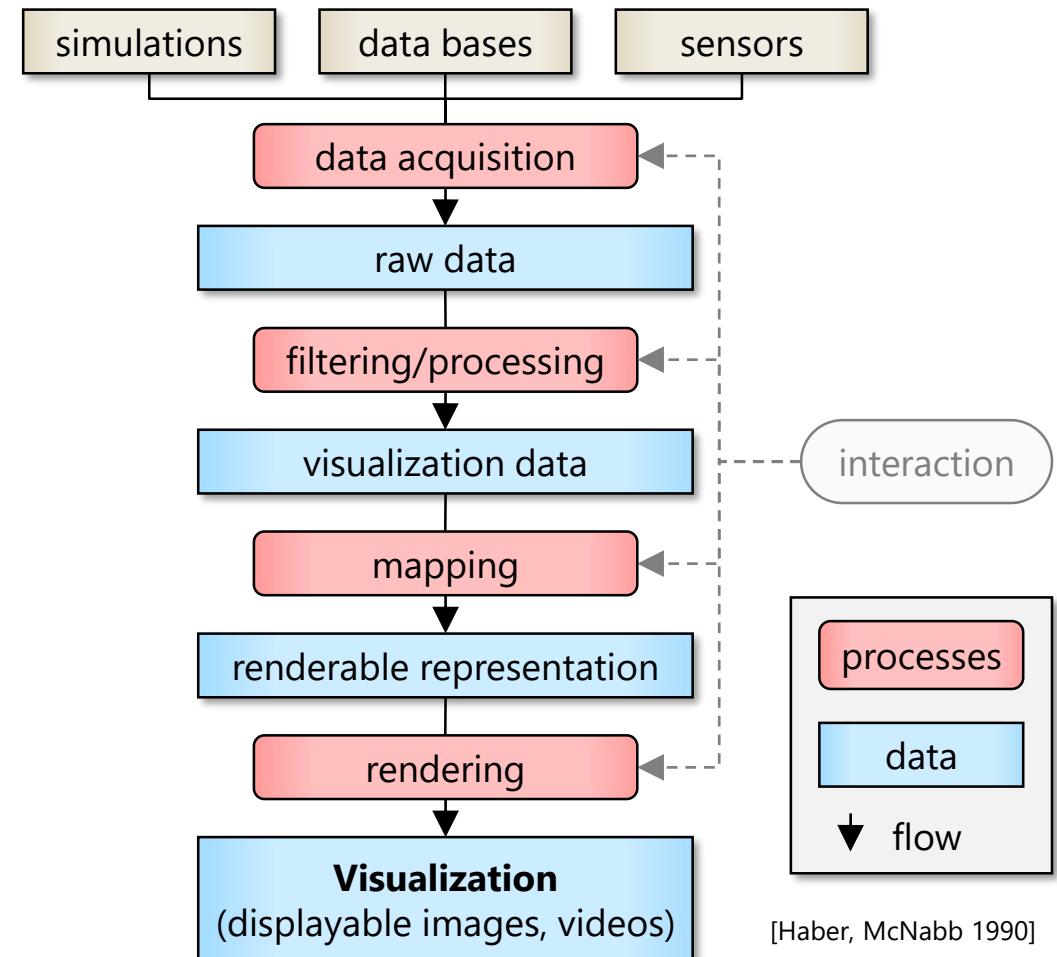


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The Visualization Pipeline

Data sources:



[Haber, McNabb 1990]

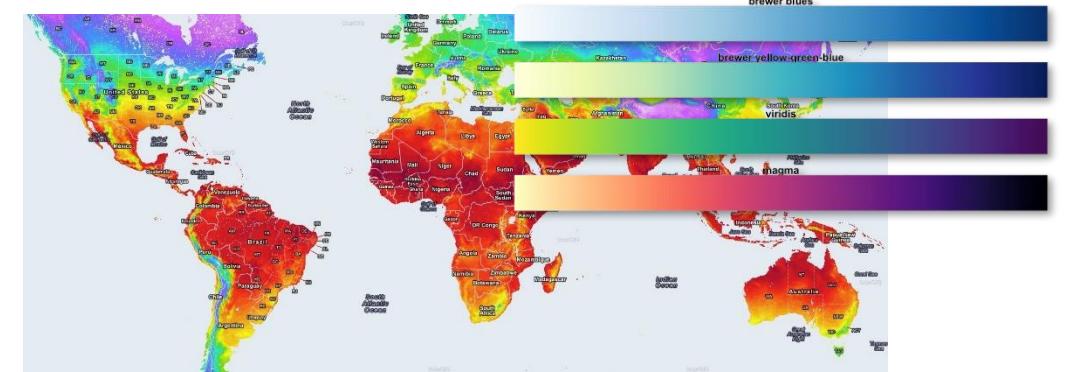
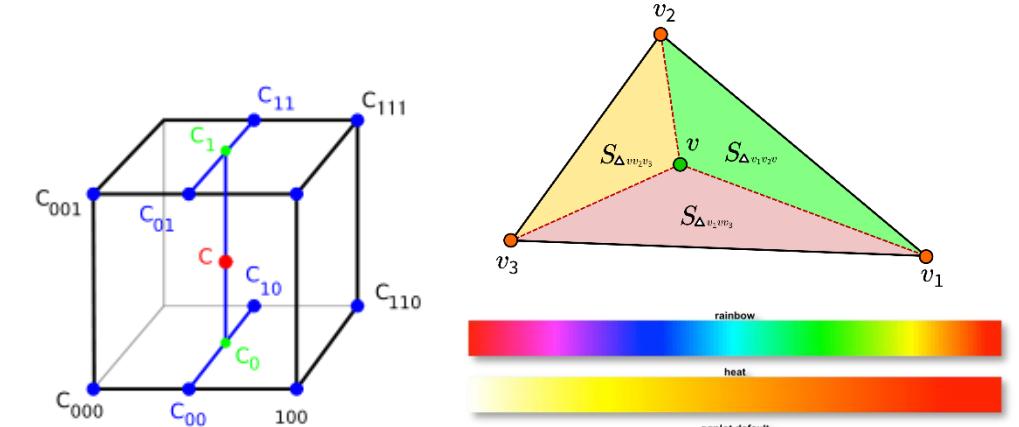
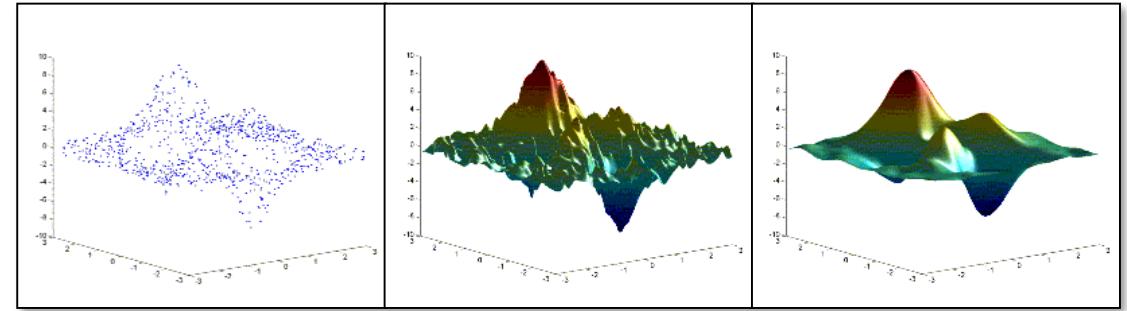
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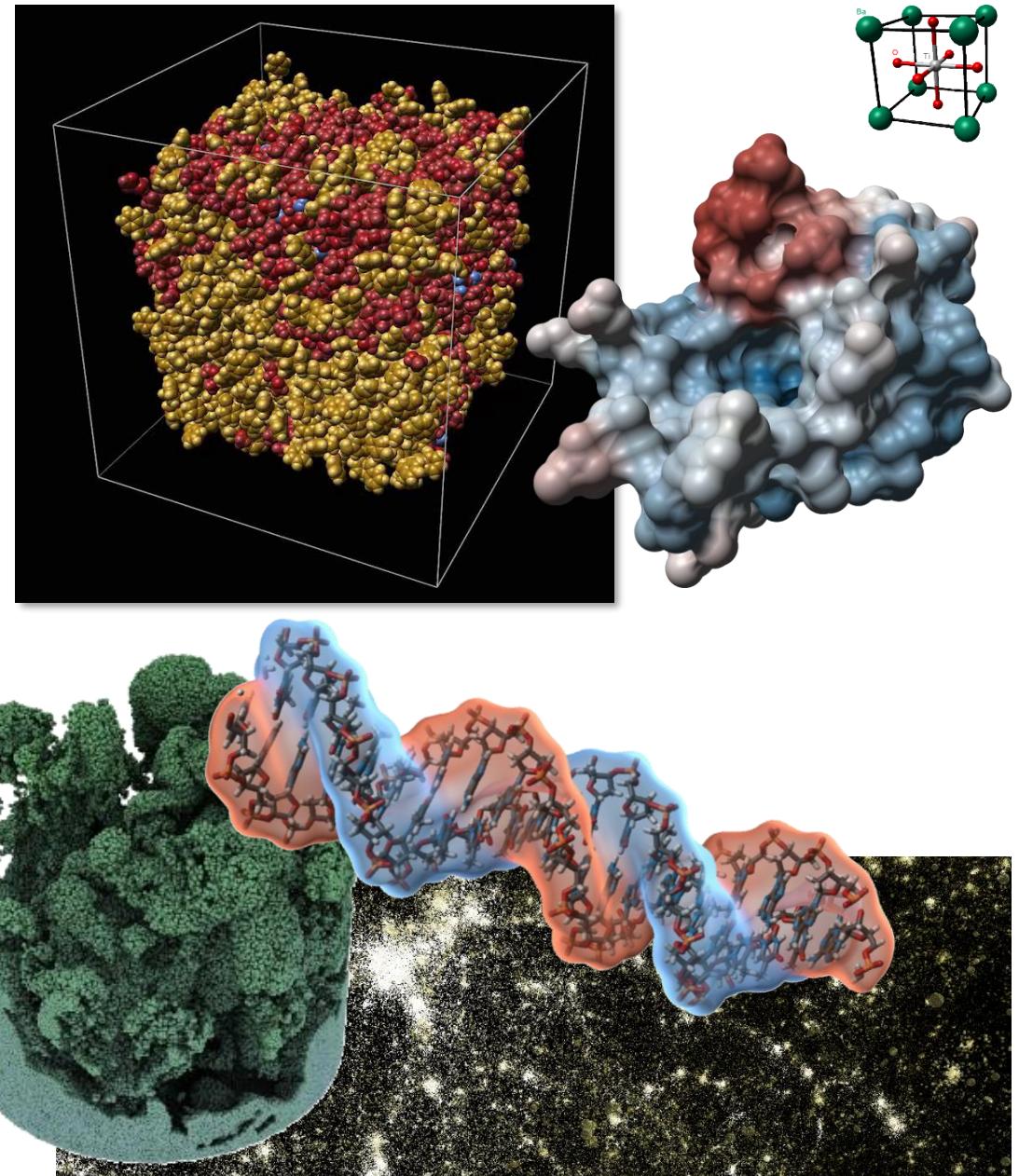
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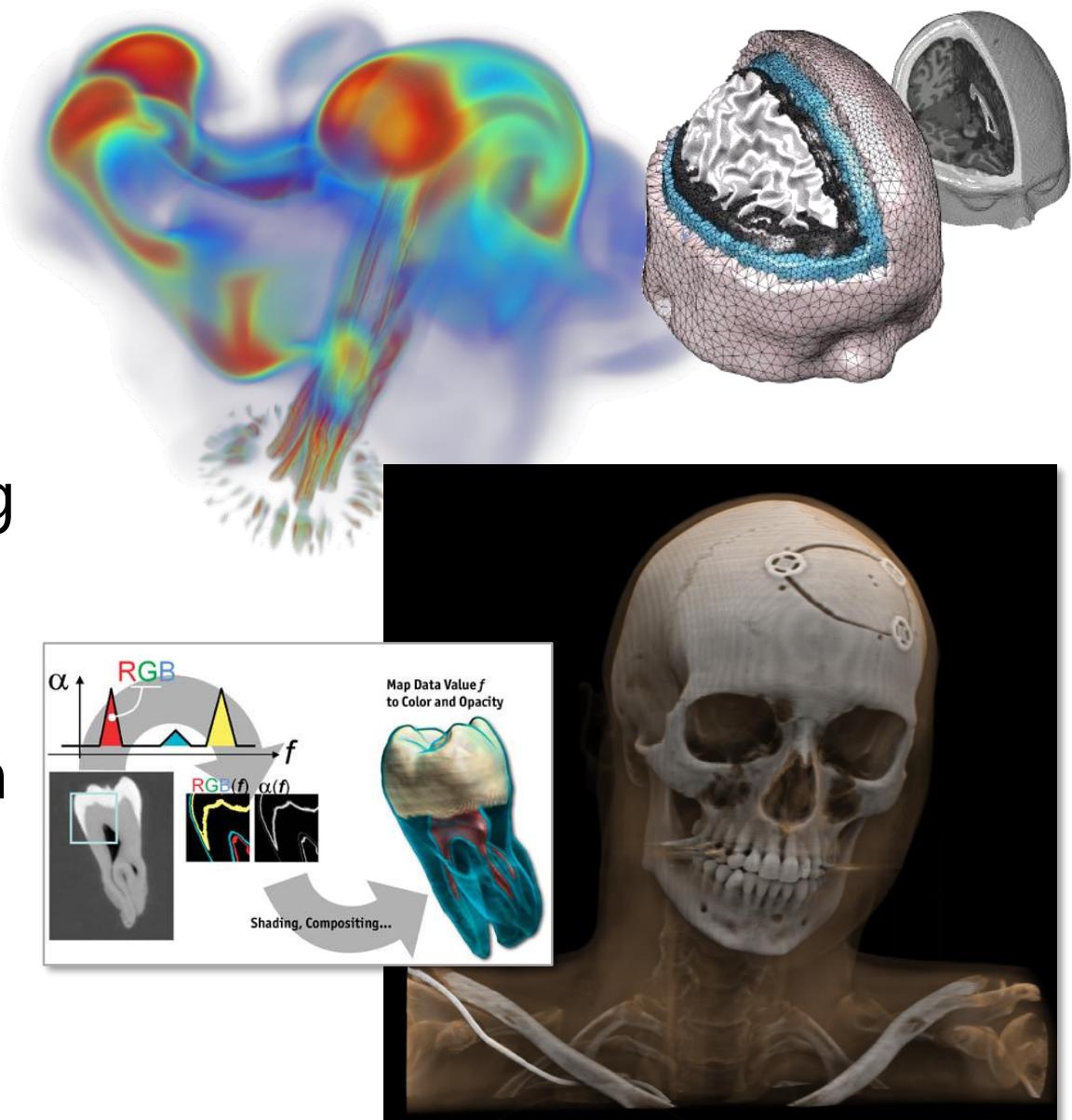
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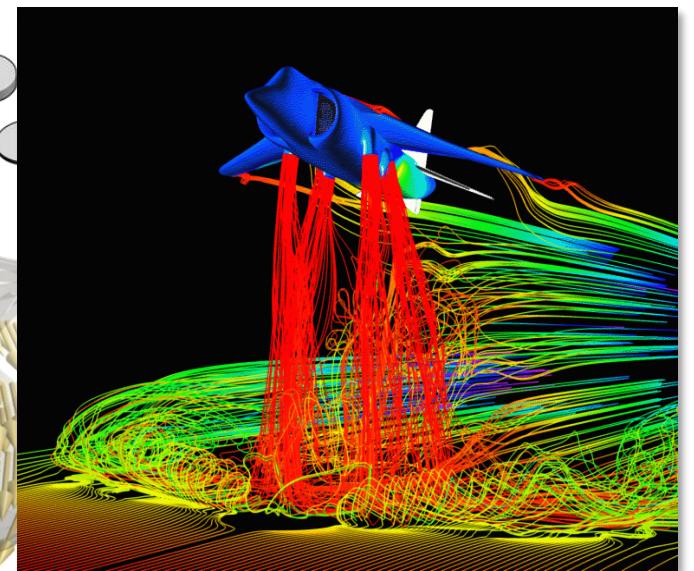
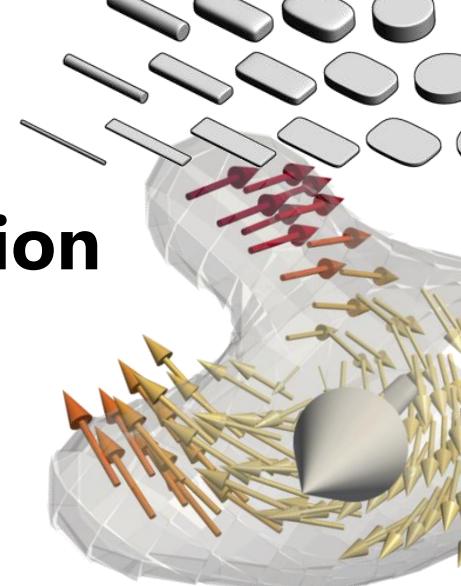
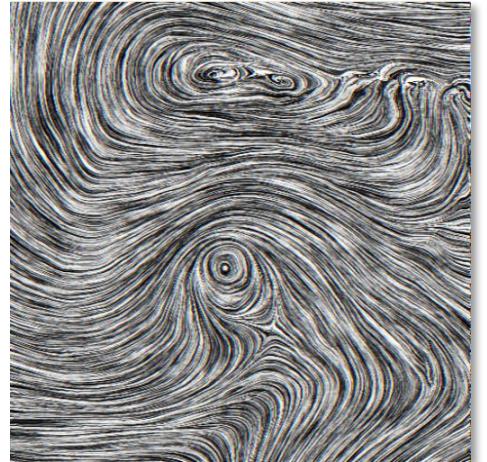
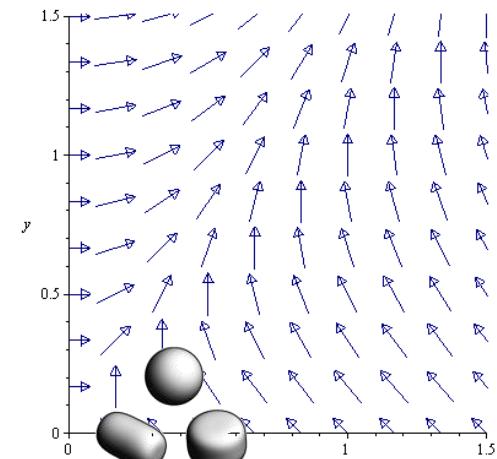
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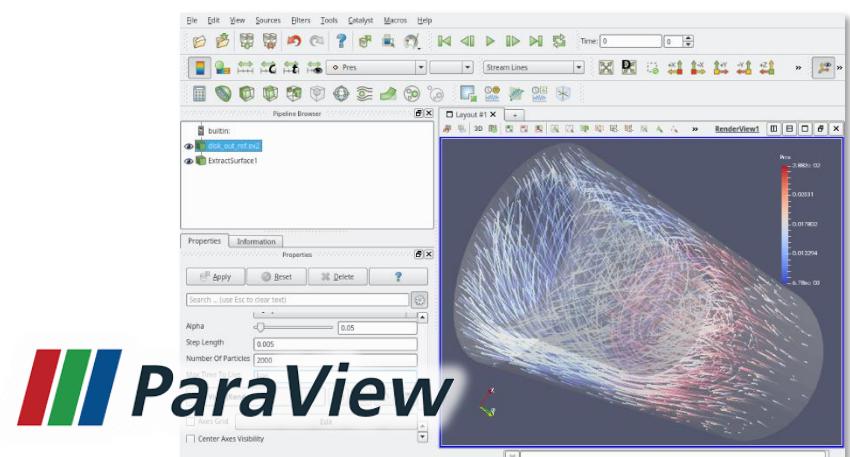
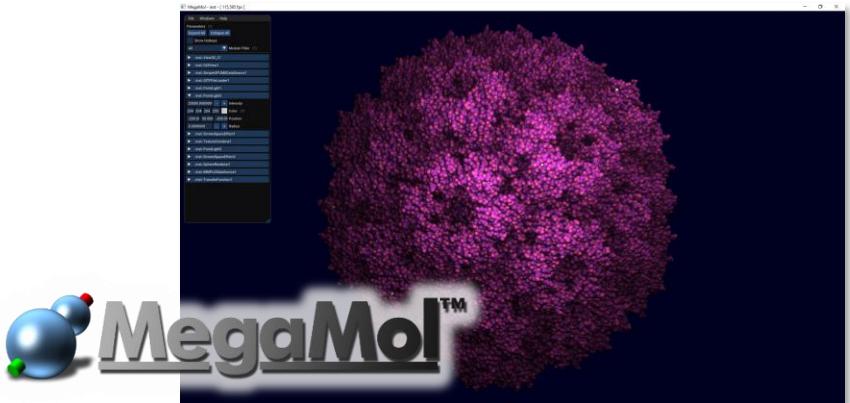
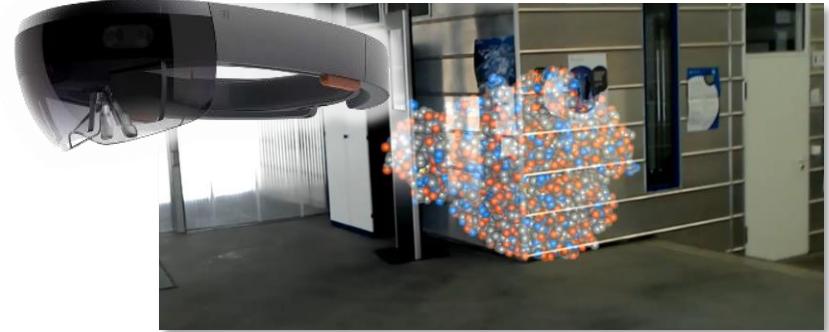
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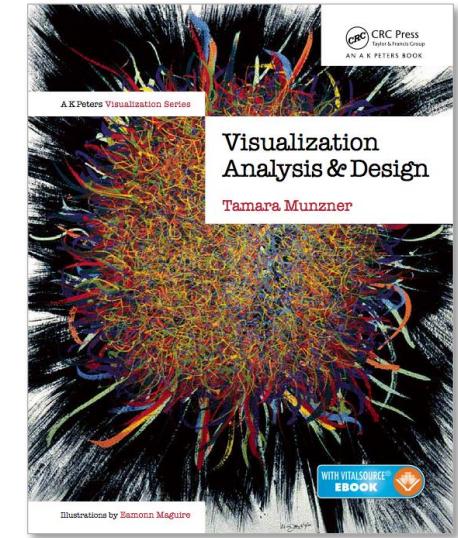
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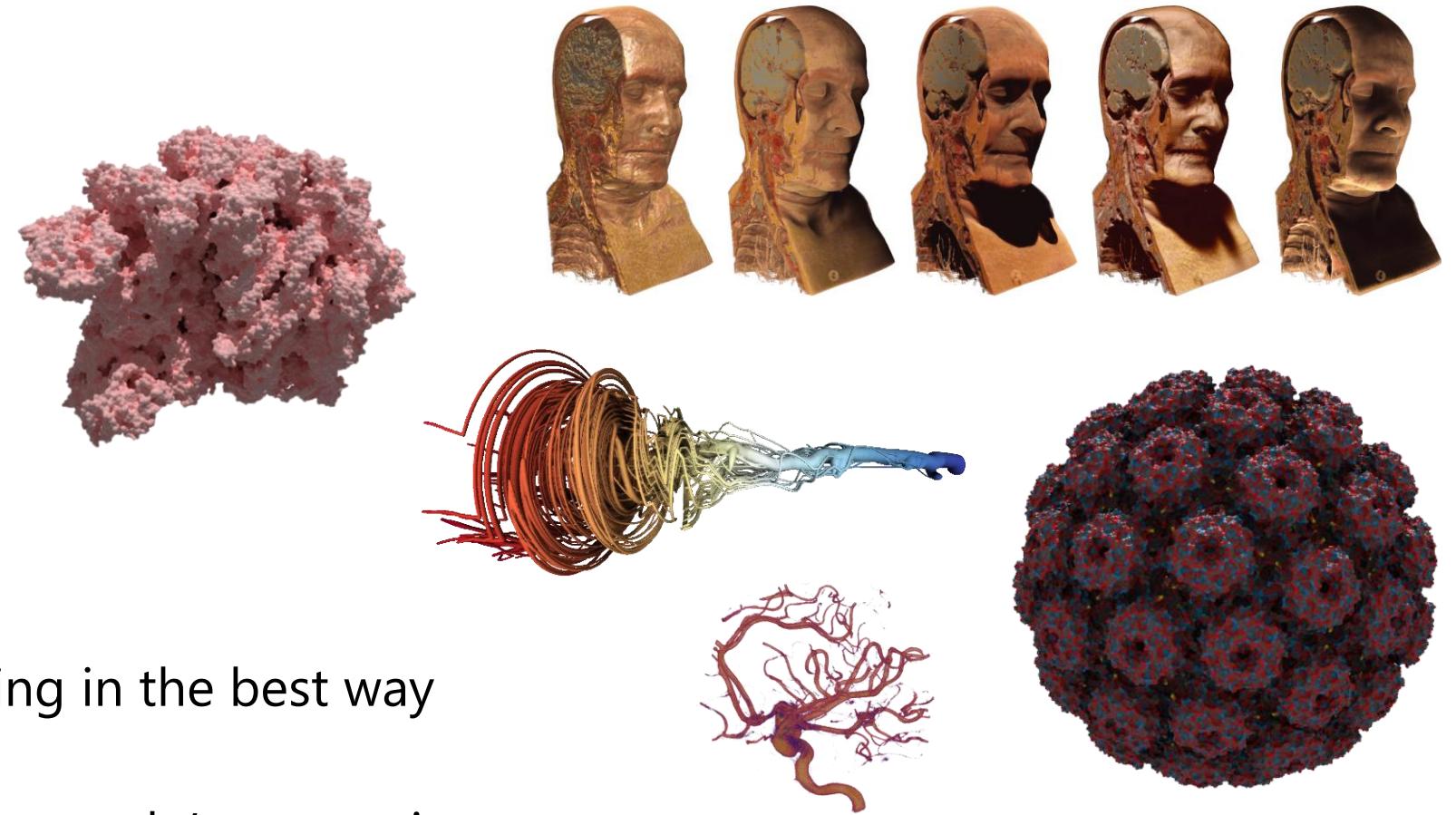
How does SciVis interact with other courses?

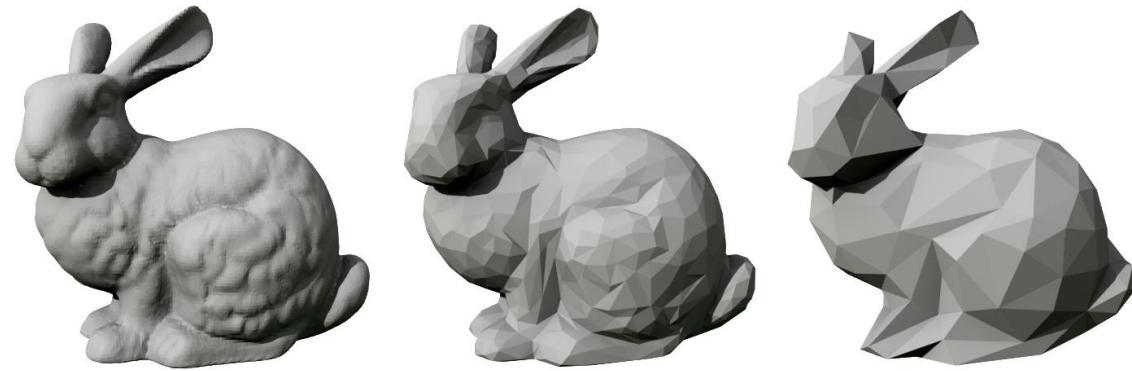
- **Visualization of Biological Data**
 - Introduction to Information Visualization with examples from biology (*no need for deep biological knowledge!*)
 - Visualization of abstract data, visual design, Visual Analytics,...
→ usually in winter semester
- **Graphische Datenverarbeitung (GDV)**
 - Introductory course to computer graphics
→ usually in winter semester (Prof. Dr. Hendrik Lensch)
- **Medizinische Visualisierung**
 - Some overlap, focus on medical data & signal processing
→ usually in winter semester (Prof. Dr. Andreas Schilling)



Scientific Visualization – Educational Goals

- Visualization specialist
- Theory
 - Classification
 - Algorithms
 - Visual design
- Application
 - Methods
 - Visualization packages
- Experience
 - How to visualize something in the best way
- Foundations
 - Bachelor/Master thesis, research/team project...
 - Possibility to work in a research group, e.g., as a student assistant (HiWi-Job)





NEXT CHAPTER:

Introduction to Computer Graphics

