Scientific Visualization

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Course Structure Summary

- Introduction to SciVis
- Data type and data operation
- Contour and iso-surface extraction
- Vector/tensor field visualization
- Volume rendering and transfer function
- Information visualization
- Visualization system and development platform

The course Grade

- Thinking problem:20%
- Presentation:30%
- Project:50%

Course Home Page

- Main source
  - Readings, lecture slides, all information
- Website
  - Courses.zju.edu.cn “学在浙大”

Lecture 1
Introduction

What is Scientific Visualization

- In 1987,the national science foundation (of the U.S.)started “Visualization in scientific computing” as a new discipline
- And a panel of the ACM coined the term “scientific visualization”
- Scientific visualization ,briefly defined :

  -The use of computer graphics for the analysis and presentation of computed or measured scientific data

Definitions of Visualization

- Oxford English Dictionary
  - To visualize: 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.

Definitions of Visualization

- B. McCormick, T. DeFanti, and M. Brown
  - 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 Vol. 21.6, November 1987

Definitions of Visualization

- R. Friedhoff and T. Kiley
  - 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, Vol. 13.8, pp. 46, August 1990

Definitions of Visualization

- R.B. Haber and D. A. McNabb
  - 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, in Visualization in Scientific Computing, IEEE Computer Society Press 1990.

Definitions of Visualization

- R.A. Earnshaw
  - 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

Definitions of Visualization

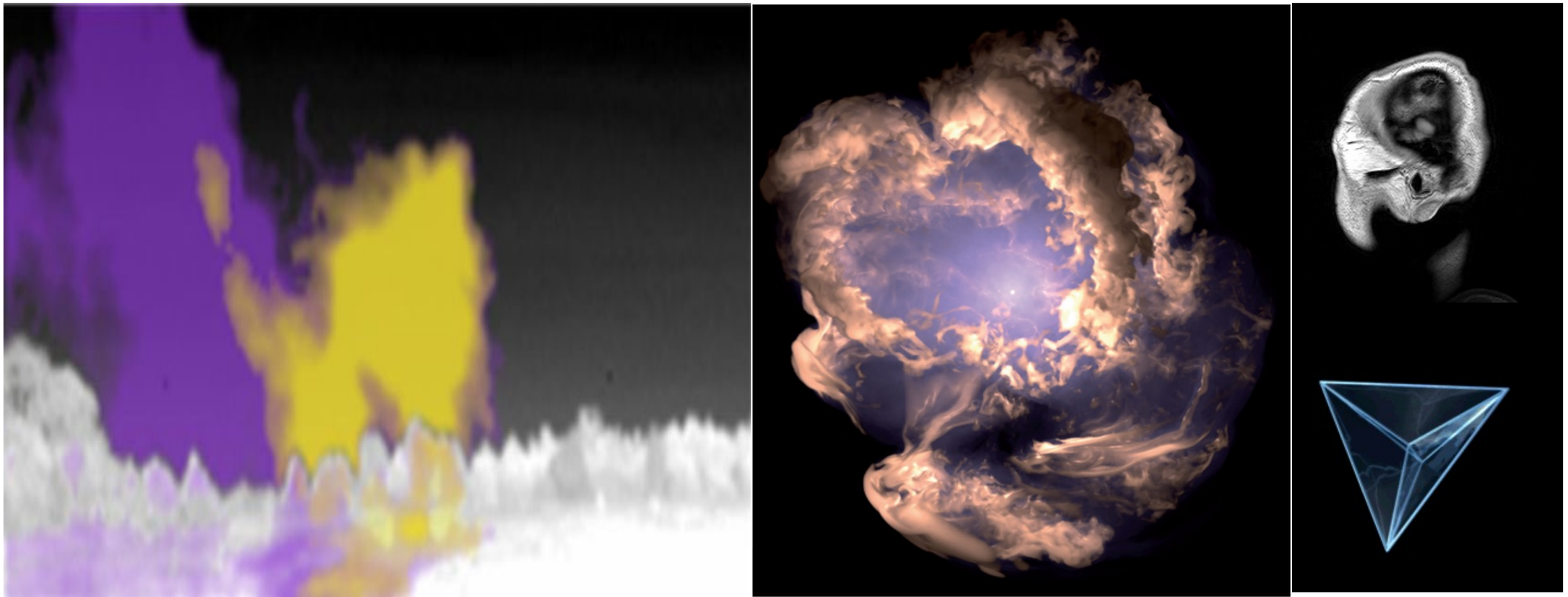
- J. Foley and B. Ribarsky
  - A useful definition of visualization might be the binding (or mapping) of data to representations that can be perceived. The types of bindings could be visual, auditory, tactile, etc., or a combination of these.
  - J. Foley and B. Ribarsky, Next-generation Data Visualization Tools, in Scientific Visualization, 1994, Advances and Challenges, Academic Press.

Definitions of Visualization

- H. Senay and E. Ignatius
  - Scientific data visualization supports scientists and relations, 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.

Scivis is interdisciplinary

- Fields of application include engineering , natural , medical sciences.



Types of data

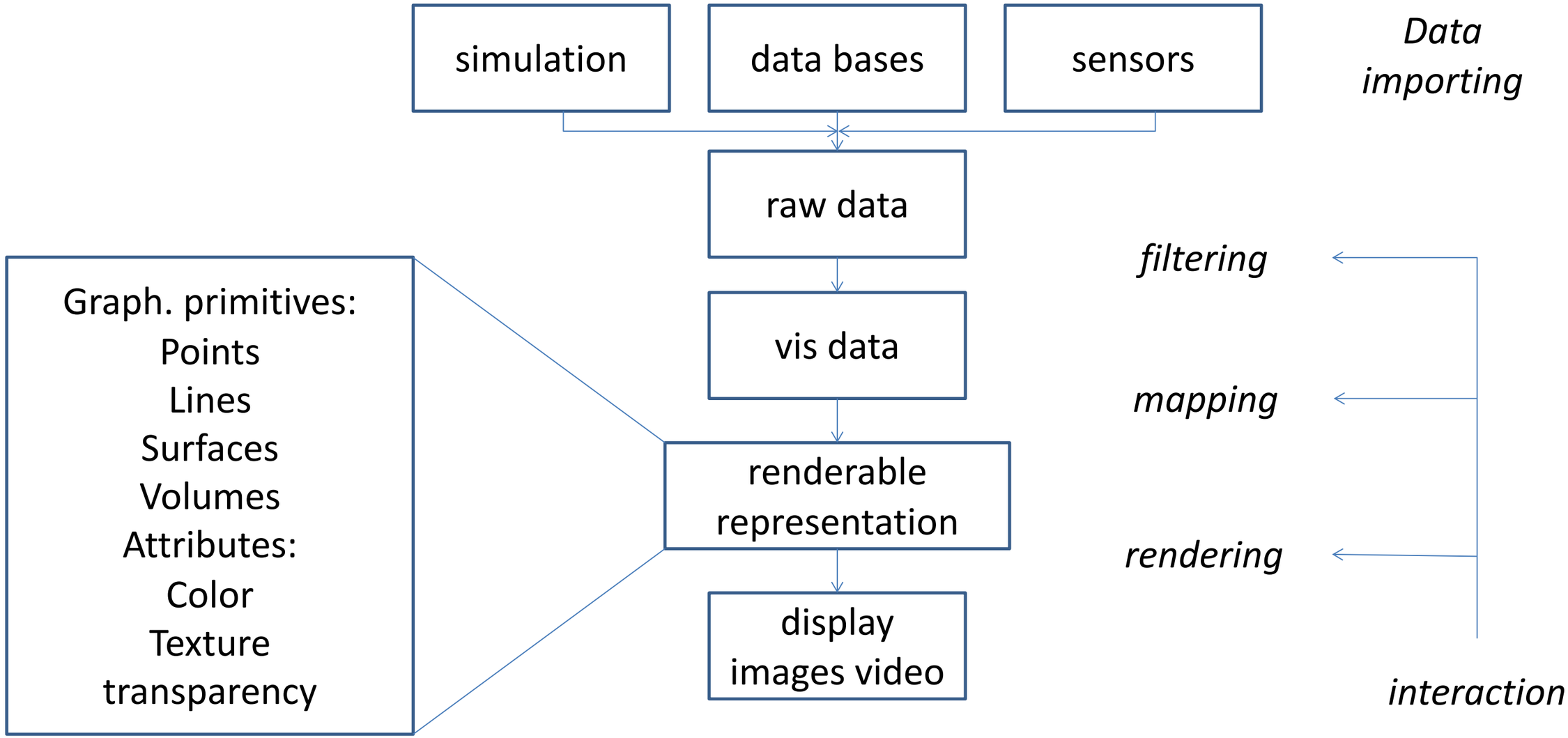
- common to all application fields: numerical datasets , providing an abstraction from the particular application.

- Characteristics of datasets:
  - Dimension of domain: number of coordinates or parameters
  - Data model : scalar , vector, tensor
  - Discrete vs. discretized data
  - Type of discretization : (un-)structured grid , scattered data,…
  - Static vs. time-dependent

SciVis vs. InfoVis

- Scientific visualization is mostly concerned with:
  - 2,3,4 dimensional , spatial or spatio-temporal data
  - discretized data
- Information visualization focuses on:
  - high-dimensional , abstract data
  - discrete data
  - Financial , statistical ,etc.
  - visualization of large trees, networks, graphs
  - Data mining: finding patterns , clusters , voids ,outliers

The visualization pipeline



The visualization pipeline

- Visualization stages
  - Data importing
  - Data filtering
  - Data mapping
  - Data rendering

filter

- Map the data to data
  - The raw data is prepared for the following steps of the visualization pipeline.
  - One example for filtering is a data format conversion into a specific format. If only parts of the data are to be visualized, a clipping or slicing can be applied. Sometimes denoising or resampling may be necessary. In case of too few measured values interpolation makes it possible to generate values between the sample points. Furthermore, data can be segmented in this step.

Mapping

- Main part of the visualization process
  - Map the data to the visual domain
- Mapping function : $map: D \rightarrow D_v$

  D: dataset

  D_v:dataset of visual features

Graph. primitives:
Points
Lines
Surfaces
Volumes
Attributes:
Color
Texture
transparency

Rendering

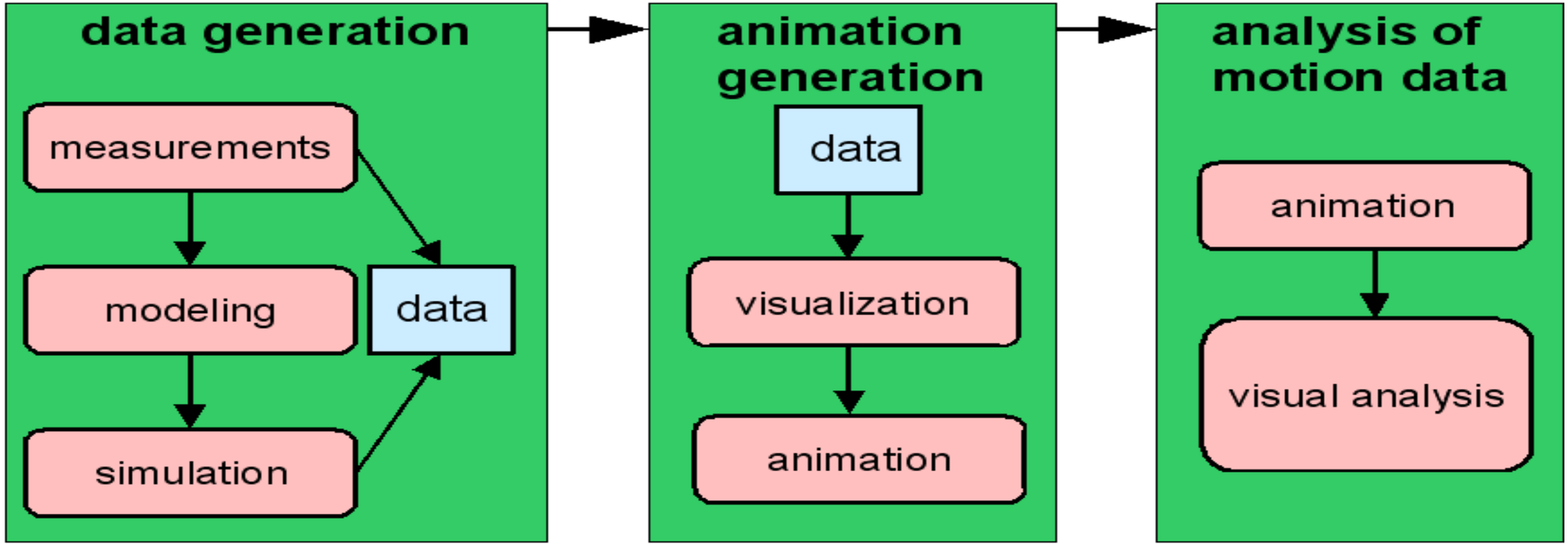
- The final step of the visualization process
  - Map the geometry data to the image data
  - Shadows, lighting, and shading are used to produce images with some degree of realism

Visualization Scenarios

- Four different visualization scenarios can be distinguished :
  - motion mode
  - tracking
  - interactive post processing
  - interactive steering

Visualization Scenarios

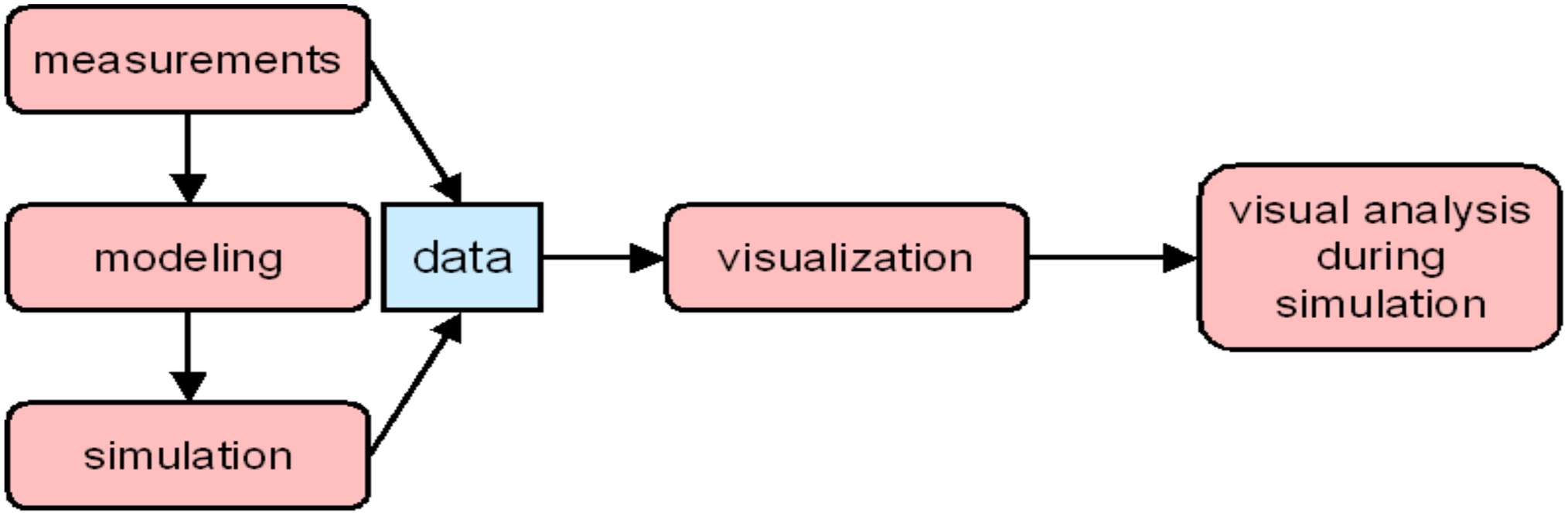
- The motion mode is based on three separated steps.
  - the whole process of data generation including modeling and simulation
  - The visualization process
  - The result of the visualization is not a single image but an animation which is viewed by the user in the visual analysis.



Visualization Scenarios

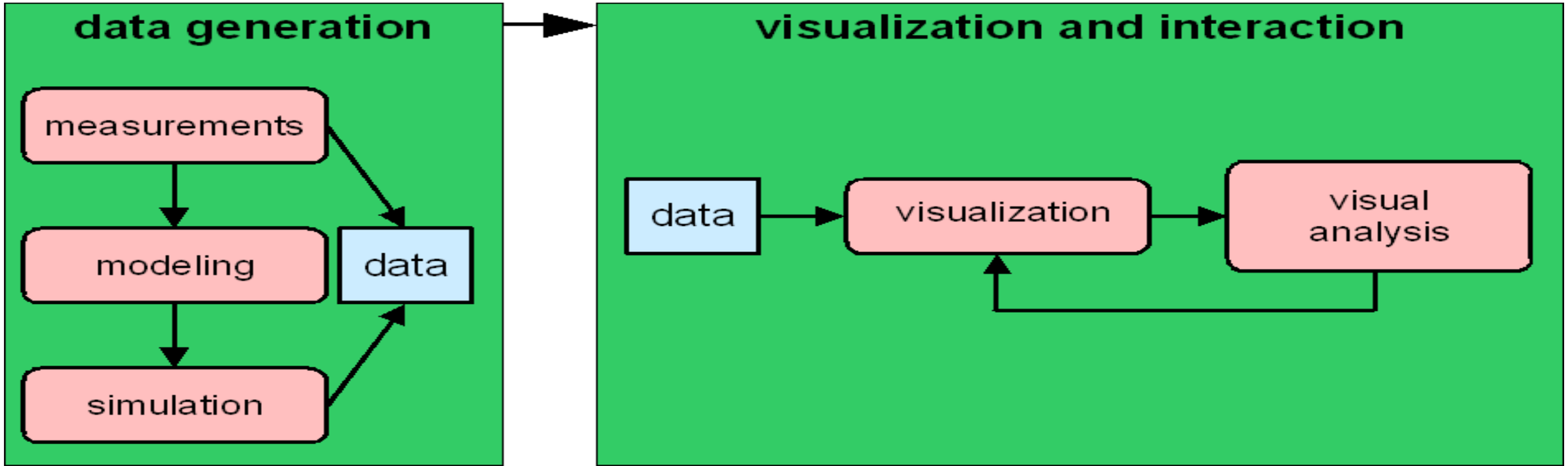
visualization scenario tracking

- the analysis process is directly connected to modeling and simulation. As soon as data is measured or calculated it is processed and offered to the analysis.

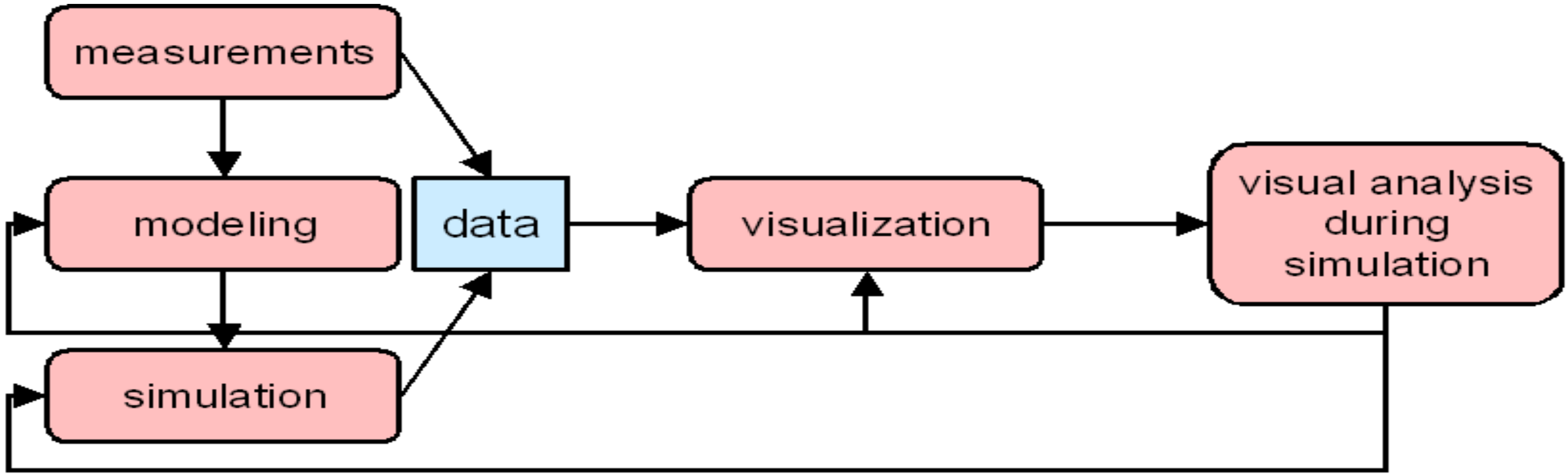


interactive post processing

- the visualization process is separated from data generation, modeling, and simulation.
- The viewer has the opportunity to interact with the visualization by possibly changing parameters for all three parts of the visualization pipeline (filtering, mapping, and rendering).



- Only with interactive steering the user can interact with the three processes modeling, simulation, and visualization.

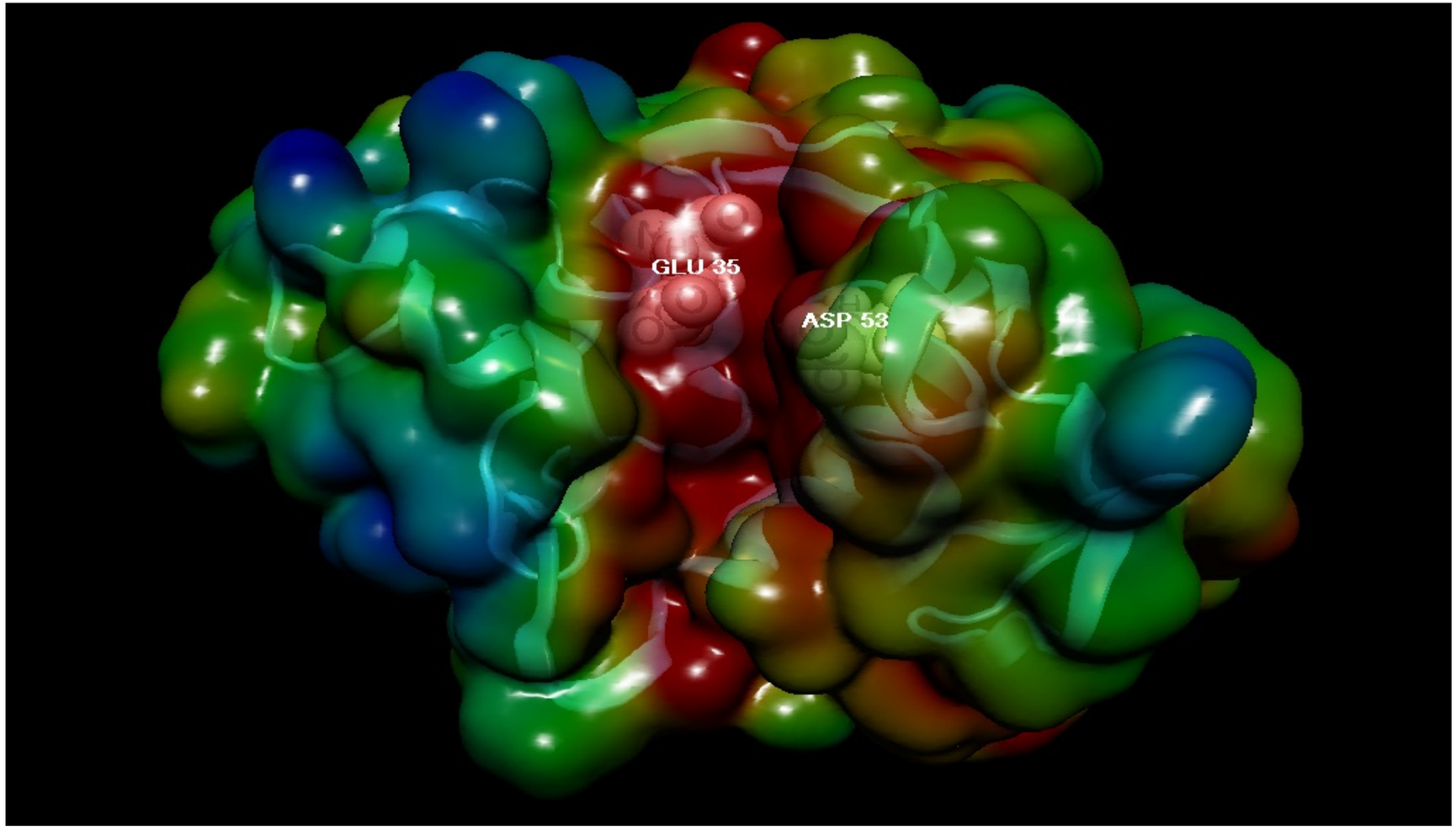


Scientific research

- Molecular modeling
- Medical imaging
- Geoscienes
- Space exploration and Astrophysics
- Mathematics

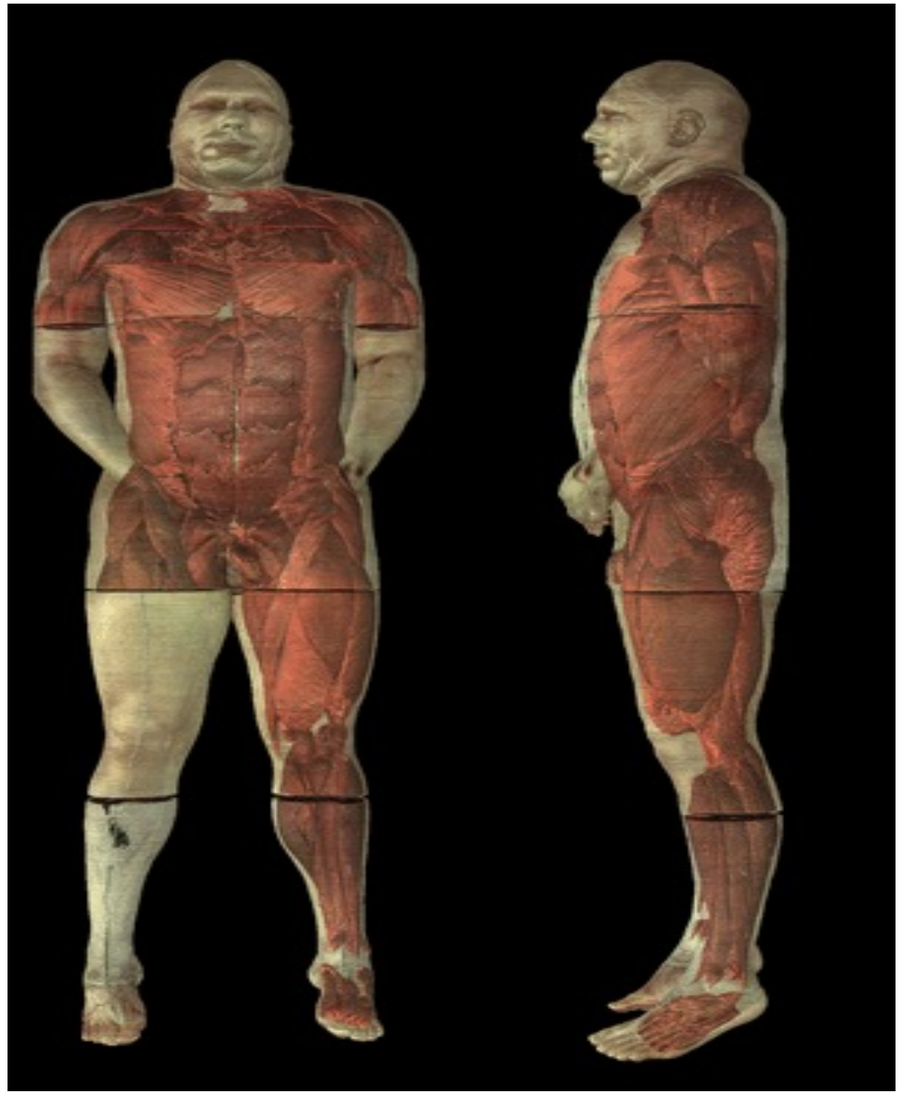
Molecular modeling

- gain insight into chemical complexity



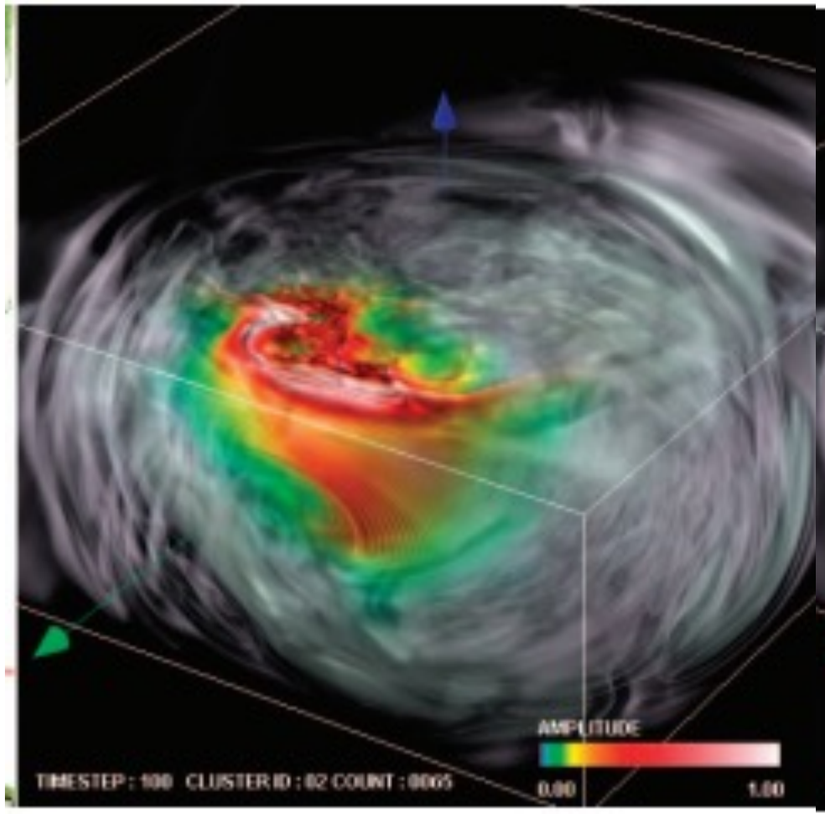
Medical imaging

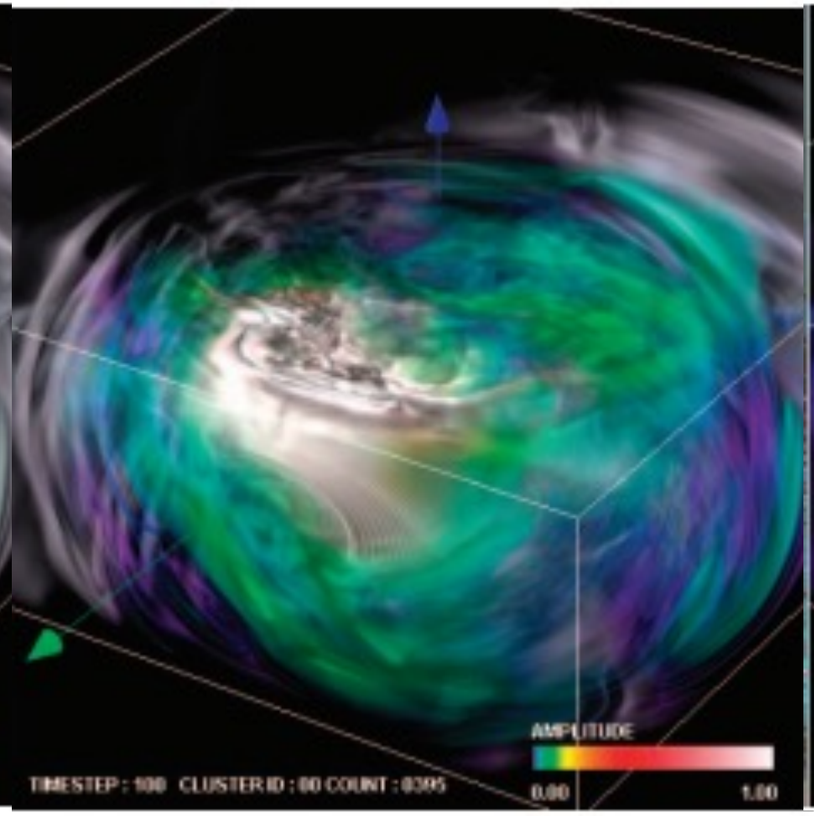
- Visualization of visible human

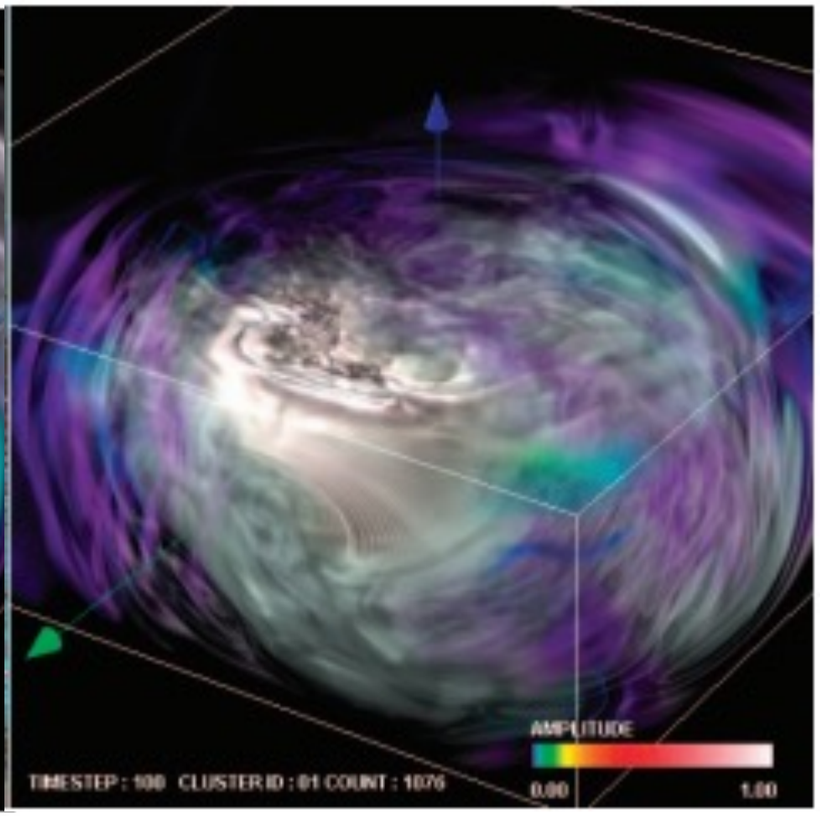


Geoscienes

- Visualization of earthquak data sets

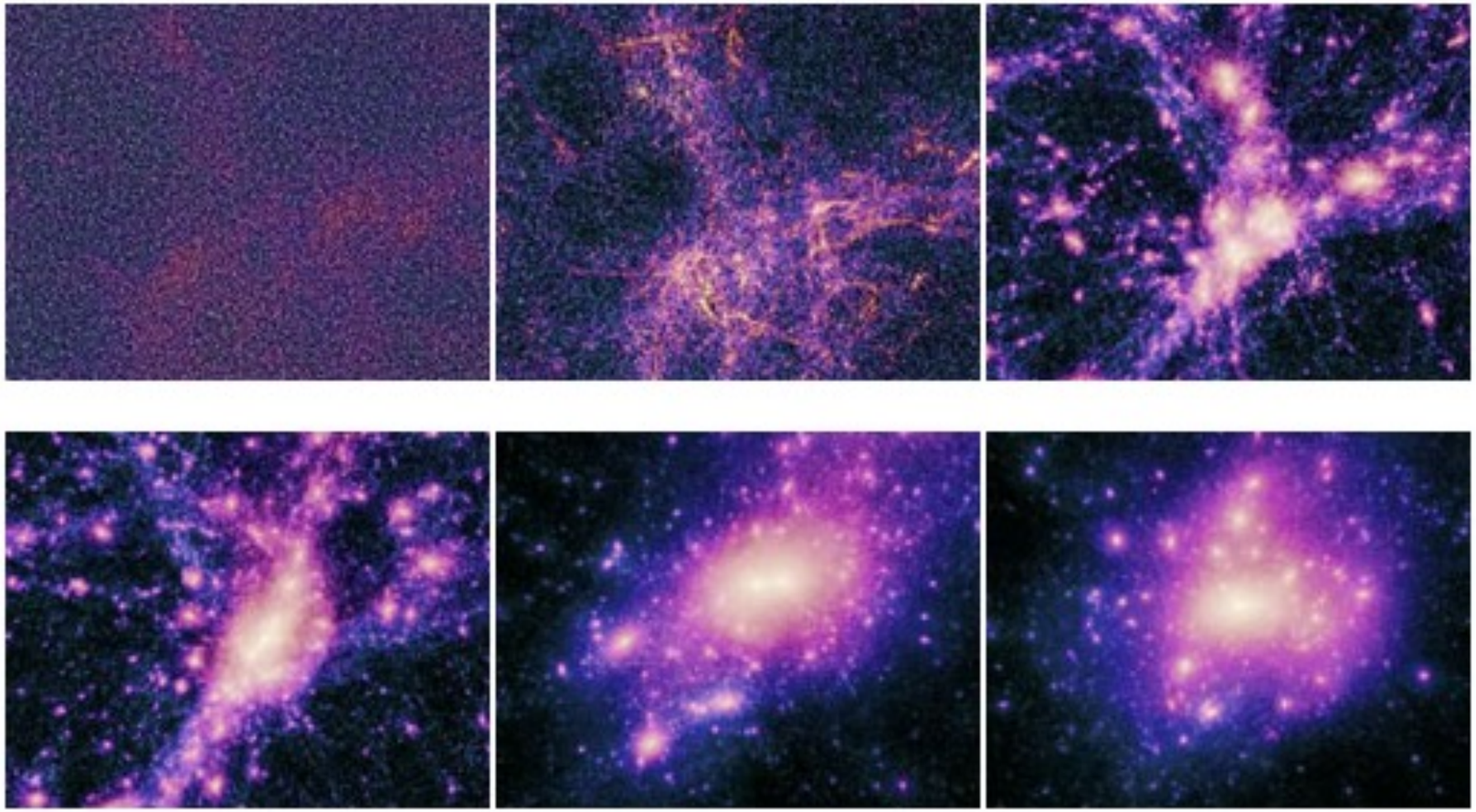






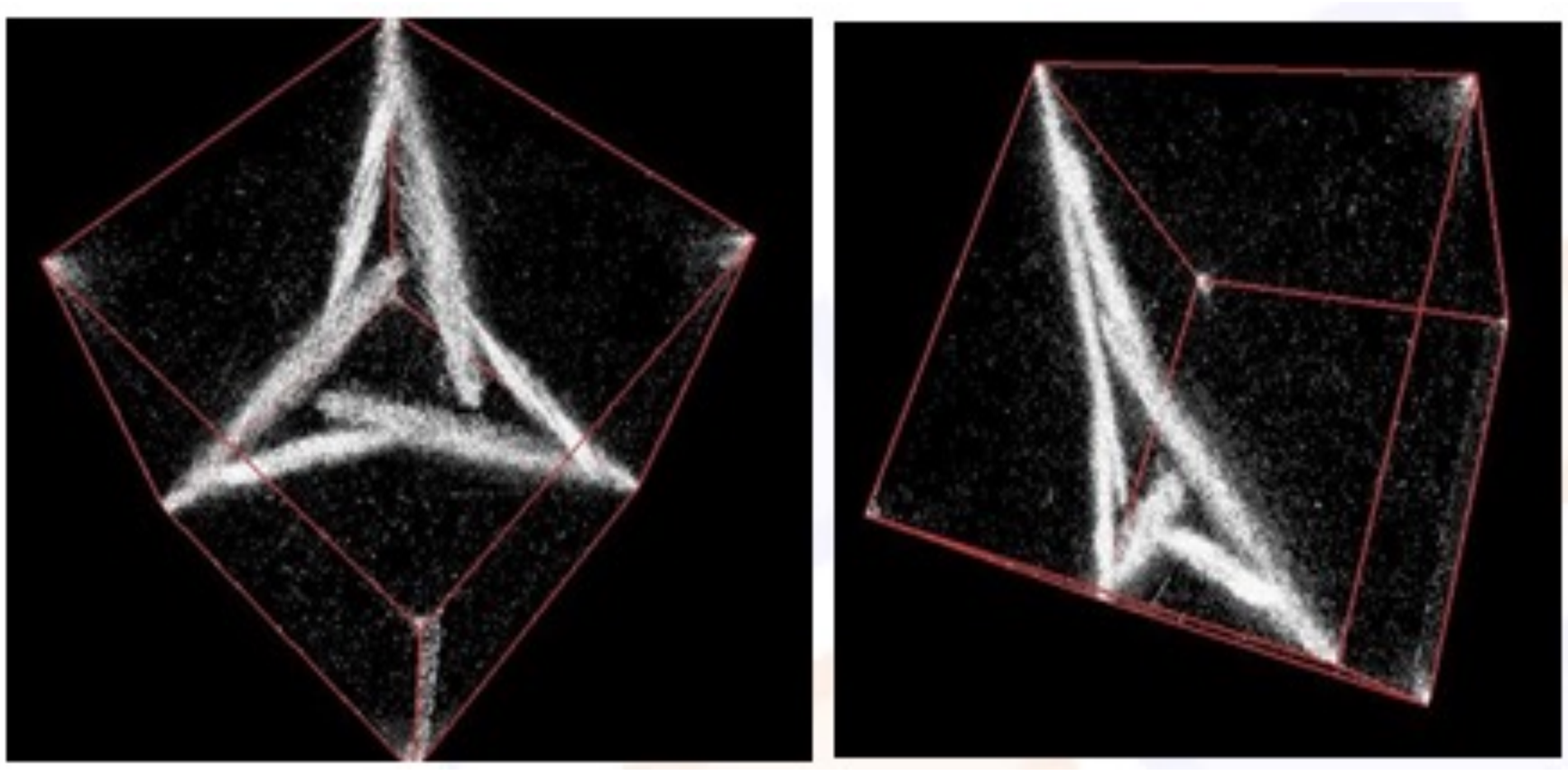
Space exploration

- Visualization of galaxies cluster



Mathematics

- Visualization of Pseudo Random Numbers

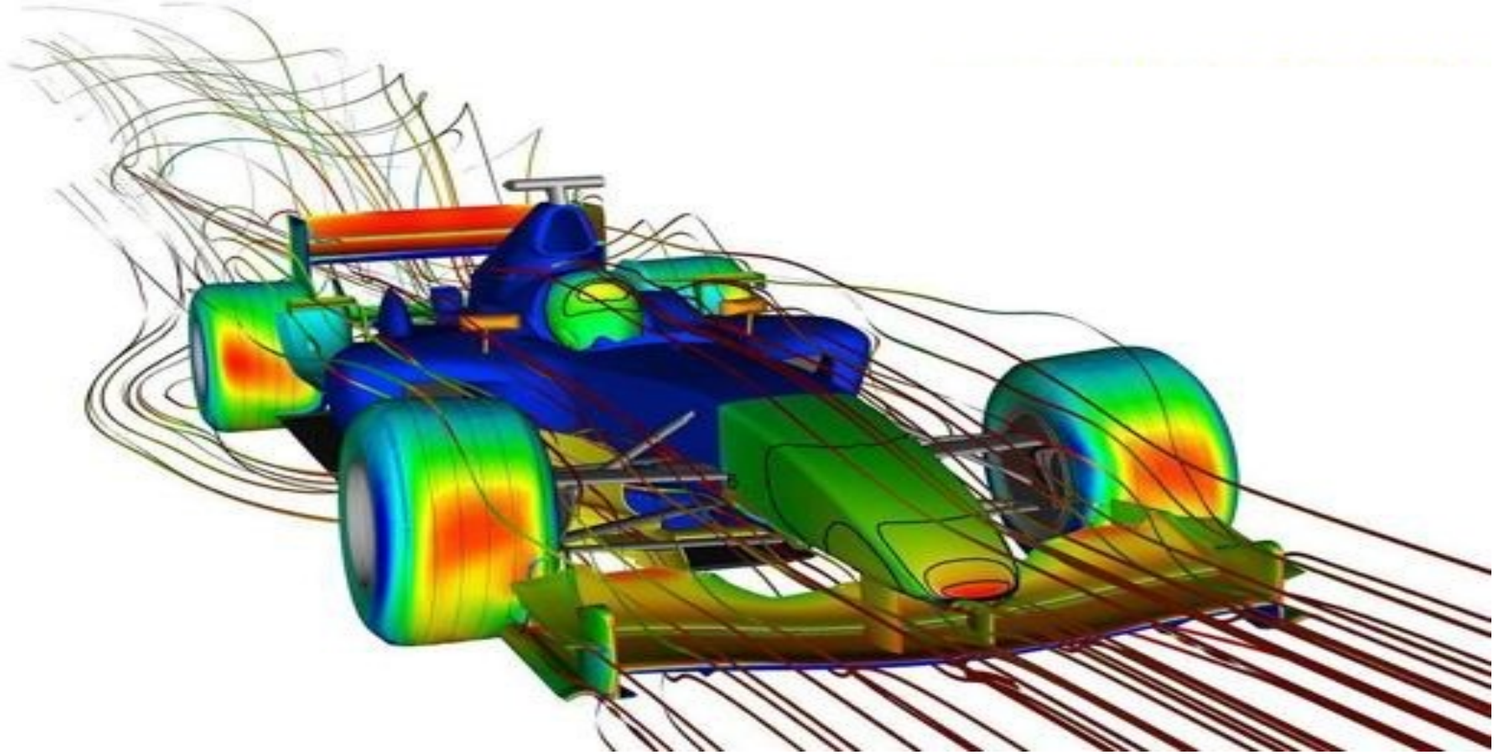


Engineering

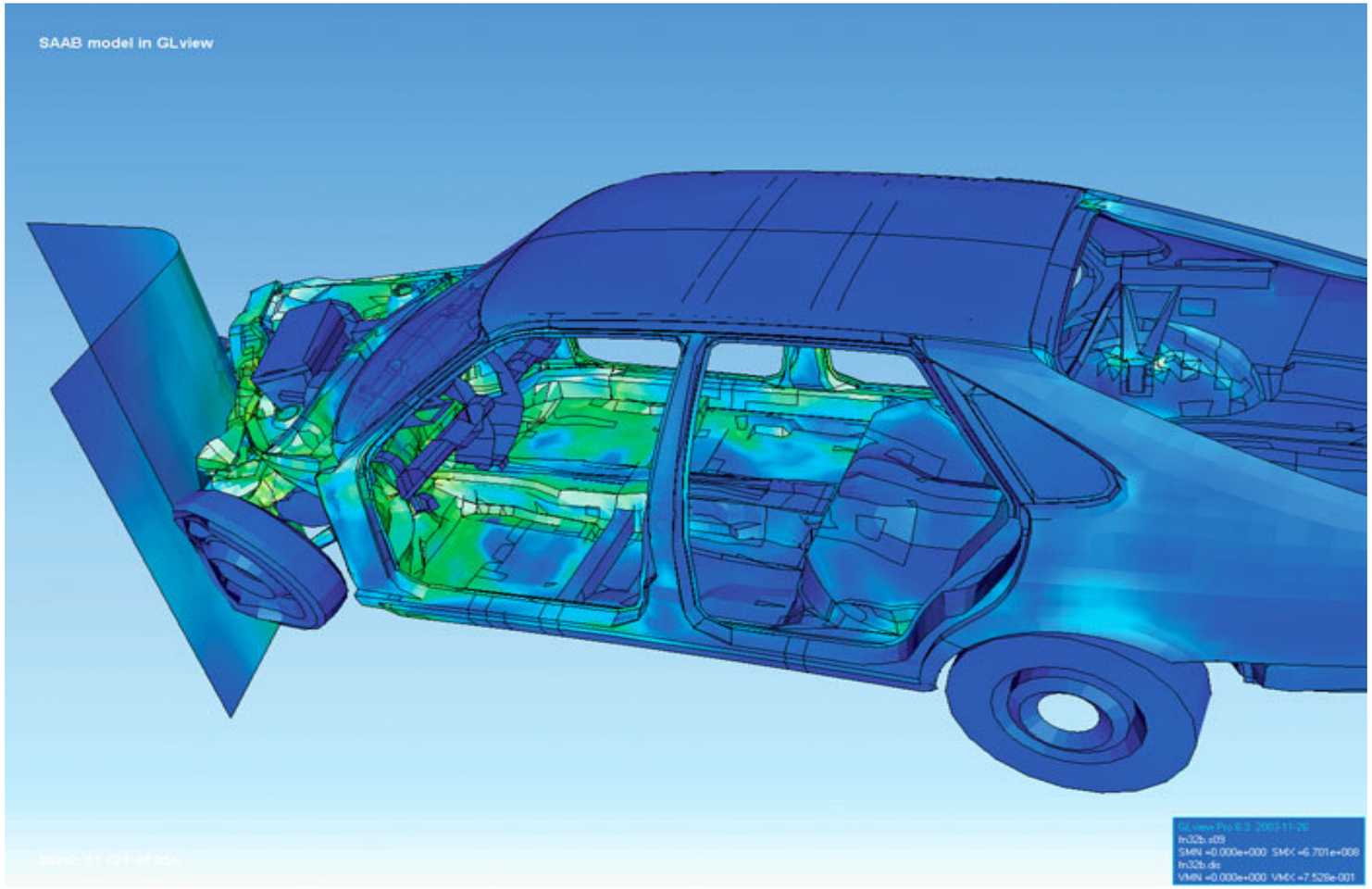
- Computational fluid dynamics(CFD)
- Finite element analysis

Computational fluid dynamics

- Predominant Issues in the field of CFD
  - Scientific computing (solution algorithms)
  - Visualization (techniques for viewing complex vector fields)



Finite element analysis



A visualization of an asymetrical collision analysis done at NTNU using the finite element analysis method

Visualization techniques

- Data model
  - Scalar Field Visualization
  - Vector Field Visualization
  - Tensor Field Visualization

Scalar Field Visualization

- Contour extraction
- Isosurface extraction
- Surface reconstruction from cross section
- Volume Rendering

Vector Field Visualization

- Glyph-based
- Texture advection
- Feature extraction
- Vector field topology

Tensor Field Visualization

- Tensor glyphs
- Tensor line tracking
- Topology of tensor fields

Preview of topics 1

- Human Vision / Data Type
  - Visual Perception and color
  - The concept and model of Visual Perception
  - Color model
  - Data field type and data operation
  - Data representation and acquisition: regular and irregular data,CT,MRI etc.
  - Data operation: sampling,interpolation,filter etc.

Preview of topics 2

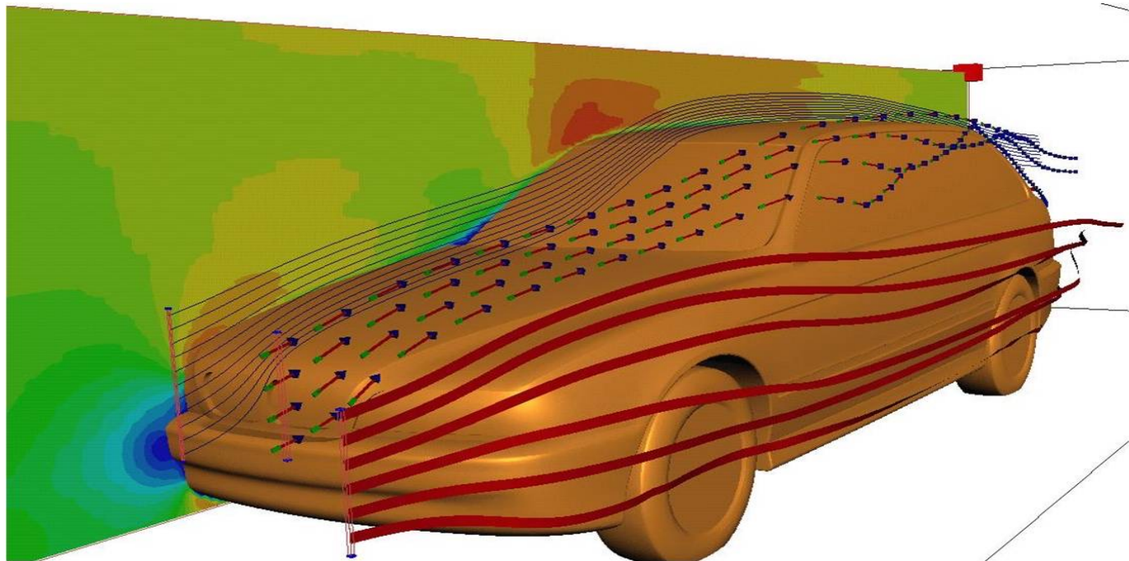
- Contouring and Isosurfaces
  - Contour / isosurface extraction
  - Surface reconstruction from cross section
  - Isosurface extraction accelation technology
  - Irregular grid data visualization

Preview of topics 3

Vector / Tensor Field Visualization

- Vector field visualization:
  streamlines integration,flow texture advectic

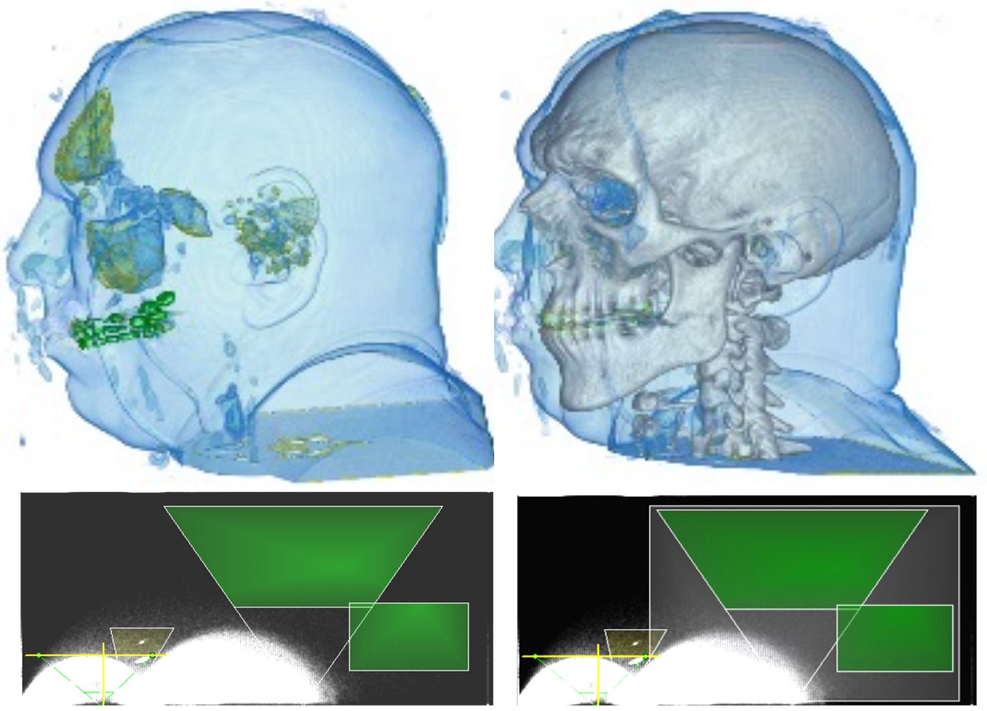
- Tensor field visualization :
  Diffusion tensor , topological methods etc.



Preview of topics 4

Volume Rendering & Transfer Function

- Volume rendering equation
- Local illumination model
- Transfer function design
  -data classification
  -1D transfer function
  -multi-dimensional transfer function etc.

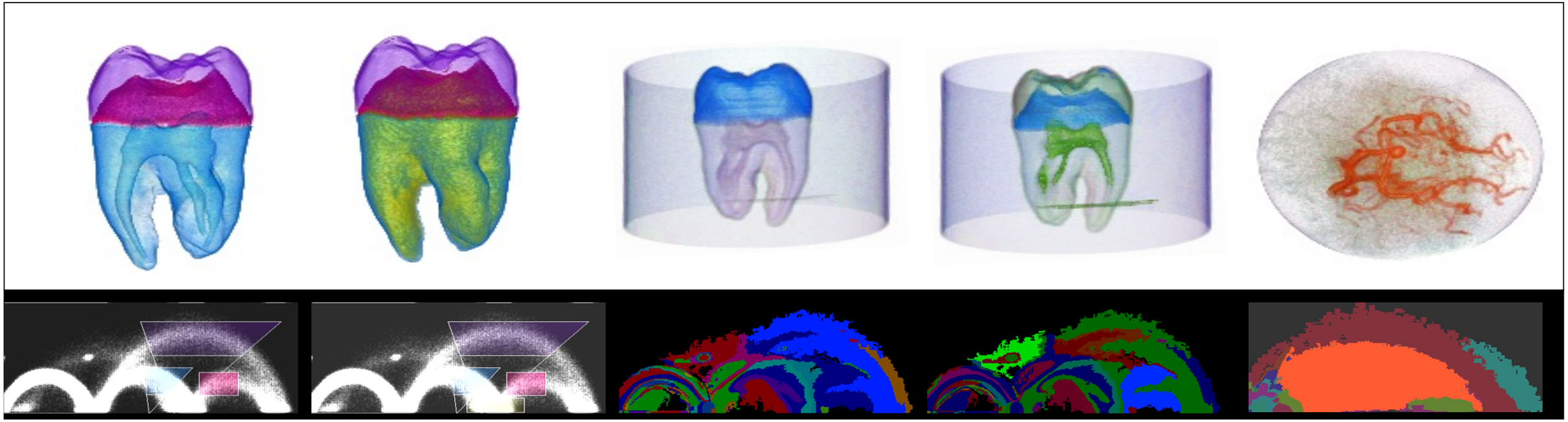


VisMale数据集128x256x256
应用基于映射窗口的多维传输函数绘制

Volume rendering platform(video)

Visualization _hailin.avi

Rendering results



Tooth dataset 256x256x161
Projection-window based multi-dimensional transfer function

Tooth data set256x256x161
Spatial information associated multi-dimensional transfer function

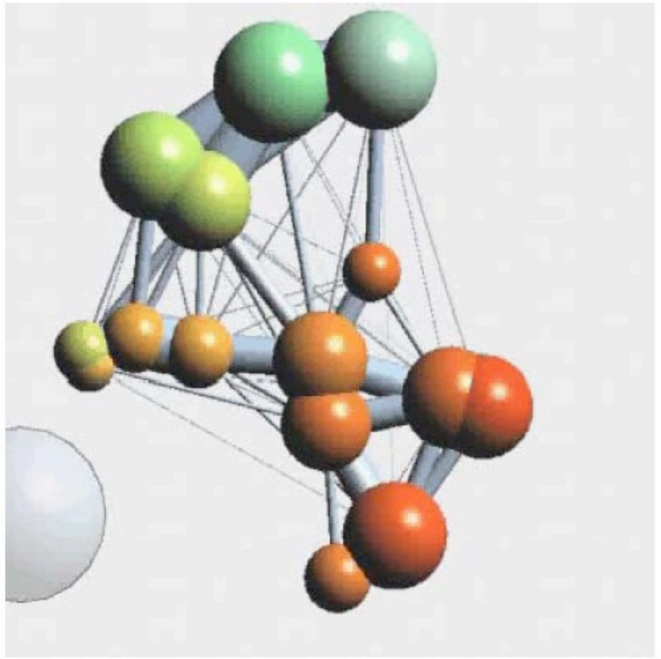
Vertebra data set
512x512x512

Preview of topics 5

- Hardware & Cluster –based Volume endering
  - Hardware accelerated volume rendering and parallel volume rendering
  - Introduction of GPU
  - GPU-based real-time volume rendering
  - Brief introduction to other volume rendering
    -shear warp volume rendering
    -splatting
  - Cluster-based large-scale data set parallel volume rendering

Preview of topics 6

- Information Visualization
  - Information Visualization
  - Principles of information visualization
  - The latest information visualization technique



Preview of topics 7

- Visualization System & Tools
  - Visualization System & platfoms
  - VTK： Visualization Toolkit
  - SCIRun： Problem-Solving Environment
  - ITK： Segmentation， Registration

Thinking problems(1)

1.联系你所在学科的研究和开发实践，思考需要“可视化”的对象或过程有哪些，请举例说明；

2.提出相应的可视化流程和可能的结果形式。

3.以主题“学号-姓名-SCIVIS”，文件命名为：
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前发邮件到助教罗钇凯：
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Thanks