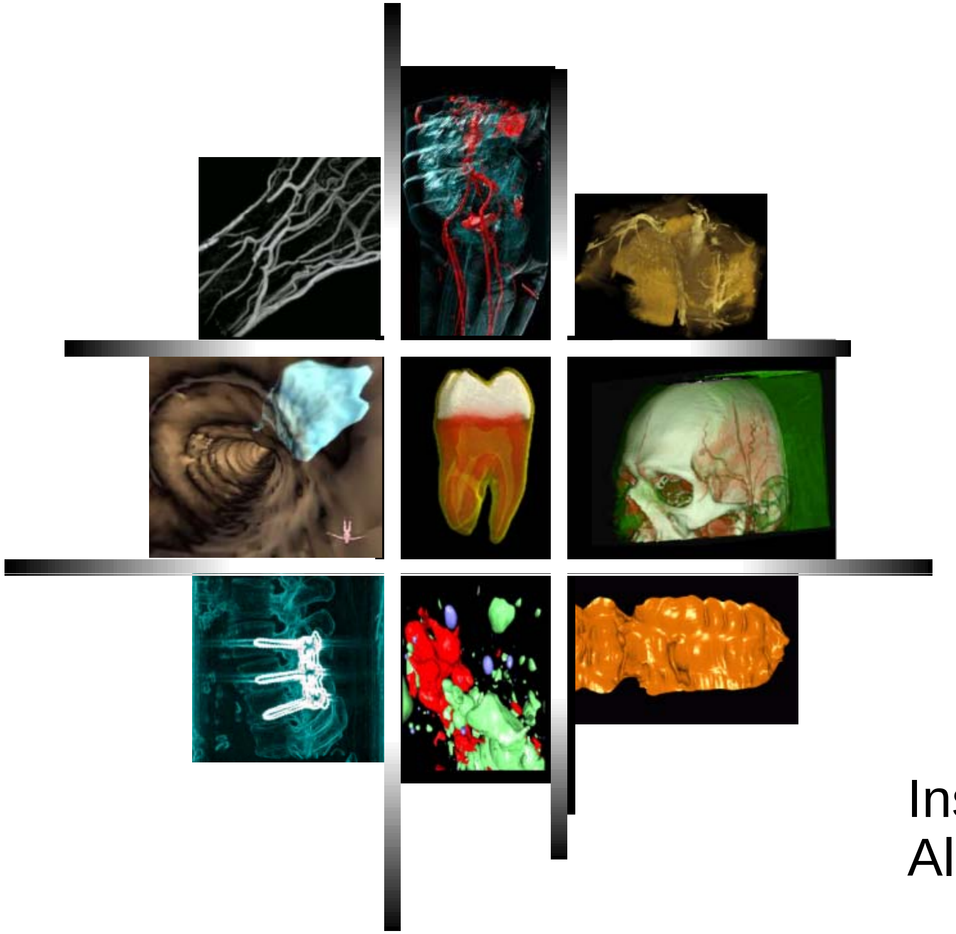
Visualisierung 1

2012W, VU, 2.0h, 3.0EC 186.827

und

Visualisierung Medizinischer Daten 2

2012W, VU, 2.0h, 3.0EC 186.138



Eduard Gröller
Stefan Bruckner
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Matthias Labschütz
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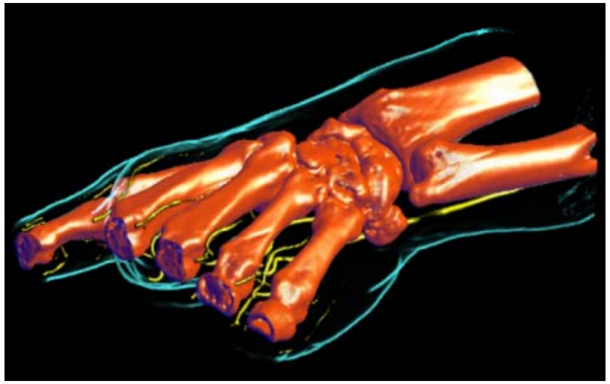
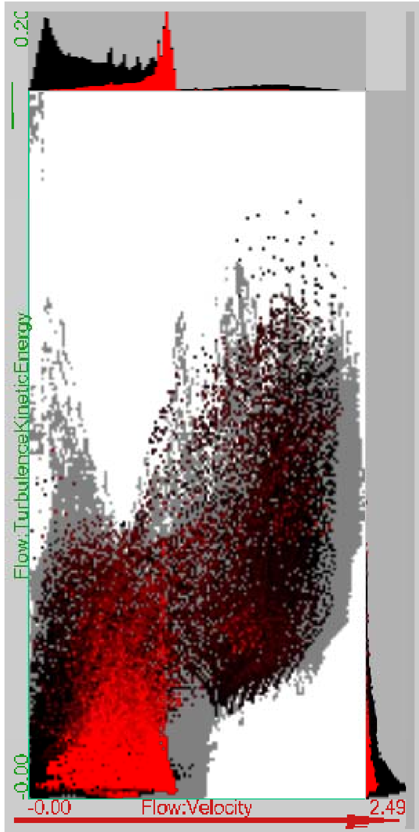
Institute of Computer Graphics and Algorithms (ICGA), VUT Austria

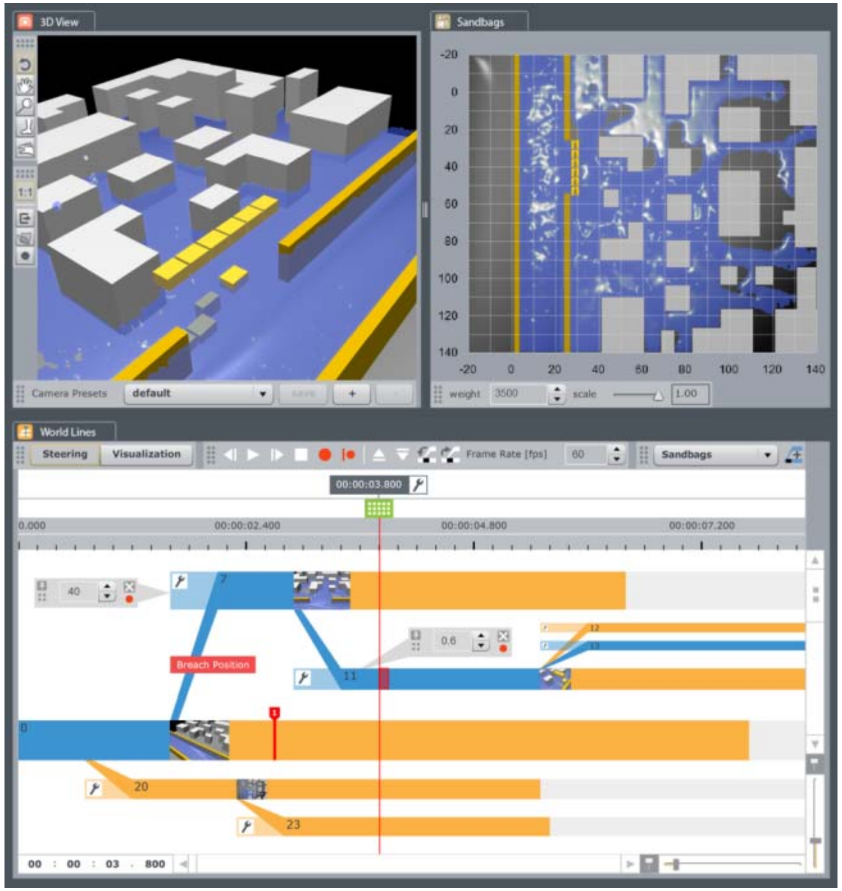
Visualization Examples

VolVis

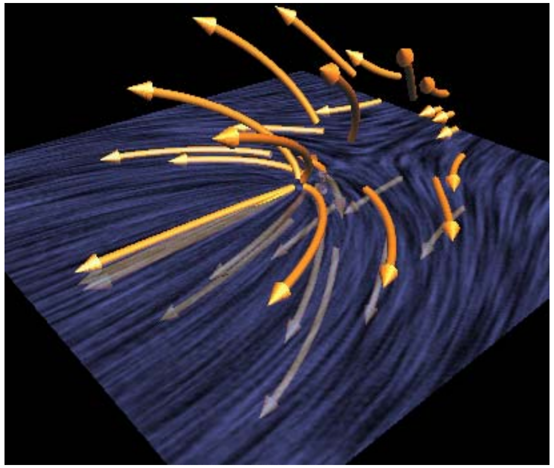


InfoVis





VisAnalytics



FlowVis

Organizational Details

- 186.827 Visualisierung 1, VU
  - 3.0 ECTS, 2 hours, lecture + exercises
  - 033 532 Medieninformatik und Visual Computing
  - http://www.cg.tuwien.ac.at/courses/Visualisierung1/VU.html
  - https://tiss.tuwien.ac.at/course/courseDetails.xhtml?courseNr=186827

- Dates lecture part
  - 1. 08.10: 09:15-10:45, EI 10 Fritz Paschke
  - 2. 22.10: 09:15-10:45, EI 10 Fritz Paschke
  - 3. 29.10: 09:15-10:45, EI 10 Fritz Paschke
  - 4. 05.11: 09:15-10:45, EI 10 Fritz Paschke
  - 5. 12.11: 09:15-10:45, EI 10 Fritz Paschke
  - 6. 19.11: 09:15-10:45, EI 10 Fritz Paschke
  - 7. 03.12: 09:15-10:45, EI 10 Fritz Paschke

Organizational Details - Labs

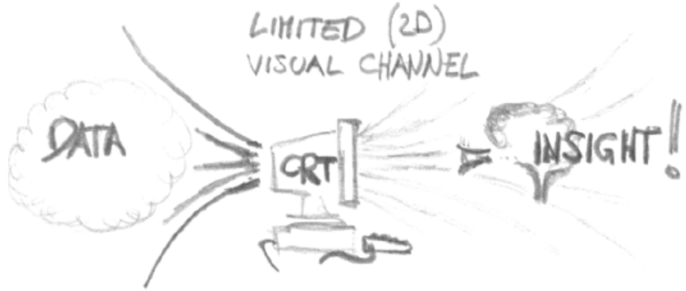
- Exercises
  - Three simple programming tasks concerning visualization pipeline
  - Framework is available
  - Reference solutions will be provided
  - Three dates to hand in the programming task
  - Details: http://www.cg.tuwien.ac.at/courses/Visualisierung1/VU.html
- Grading
  - Oral exam (colloquy) early in January (topic: programming assignments, lecture content)

- WS2012 together with Visualisierung 1
- Exceptionally and only once
- Registration in Tiss through Visualisierung 1
- Grade for appropriate course will be issued
- Exeption from the exception possible (if not too many candidates)
  - Only for students who already took Visualisierung (1) [186.138, 186.004]
  - Can do Wissenschaftliches Arbeiten (186.828)
  - http://www.cg.tuwien.ac.at/courses/WissArbeiten/index.html
  - Will get topic from medical visualization

Visualization – Definition

The purpose of computing
is insight, not numbers

[R. Hamming, 1962]

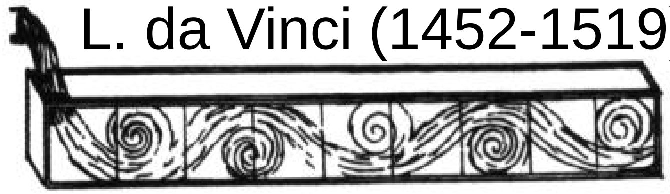


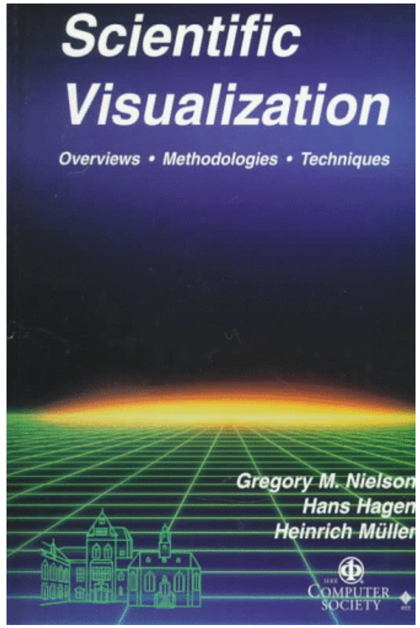
- Visualization:
  - Tool to enable a User insight into Data
  - to form a mental vision, image, or picture of (something not visible or present to the sight, or of an abstraction); to make visible to the mind or imagination [Oxford Engl. Dict., 1989]
  - Computer Graphics,
    but not photorealistic rendering

Visualization – Background

- Background:
  - Visualization = rather old
  - Often an intuitive step: graphical illustration
  - Data in ever increasing sizes ⇒ graphical approach necessary
  - Simple approaches known from business graphics (Excel, etc.)
  - Visualization = own scientific discipline since 20 years
  - First dedicated conferences: 1990

L. da Vinci (1452-1519)



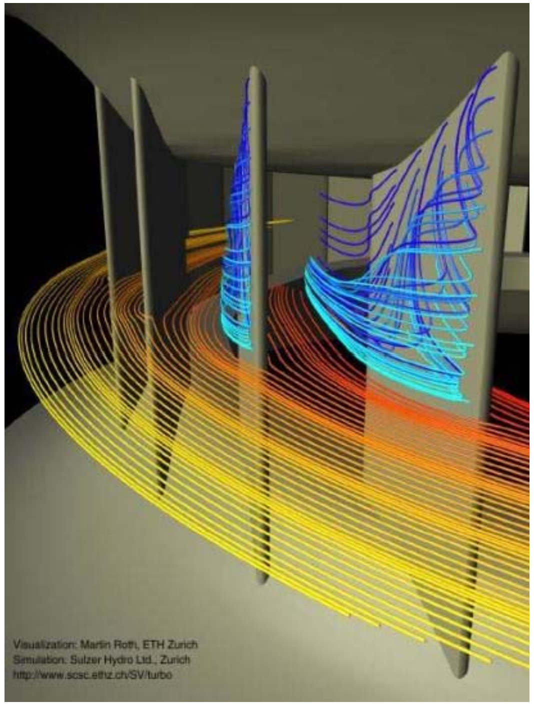


1997

Visualization – Sub Topics

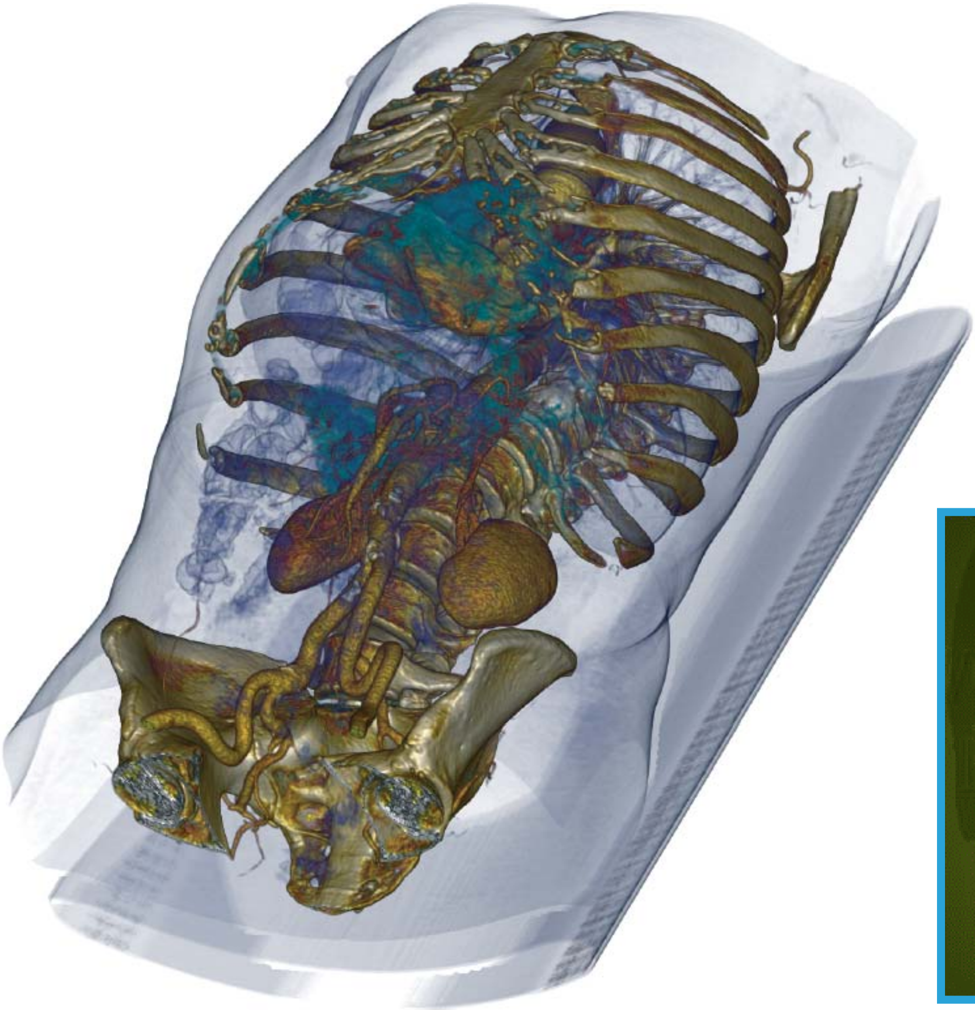
- Visualization of …
  - Medical data ⇒ VolVis!
  - Flow data ⇒ FlowVis!
  - Abstract data ⇒ InfoVis!
  - GIS data
  - Historical data (archeologist)
  - Microscopic data (molecular physics), Macroscopic data (astrononomy)
  - Extrem large data sets

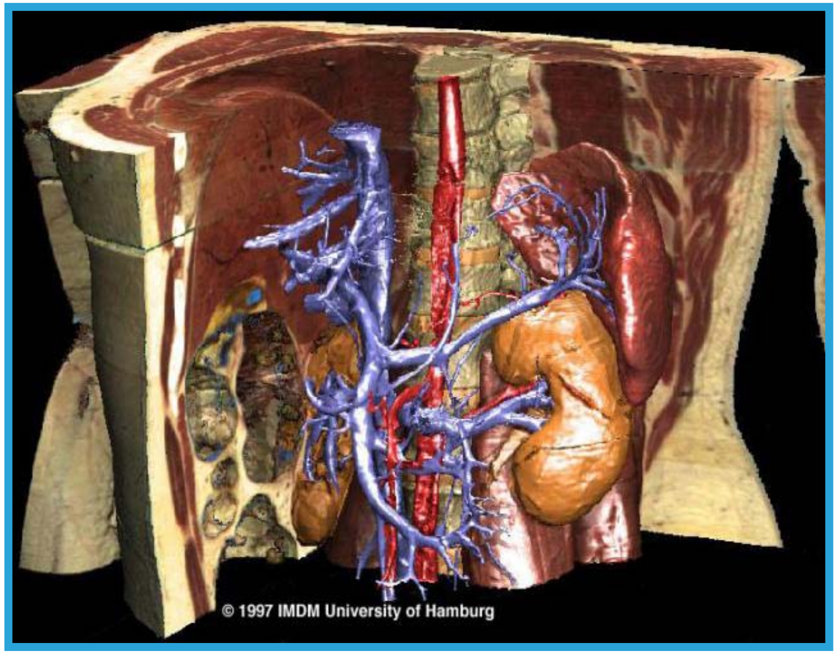
  etc. …

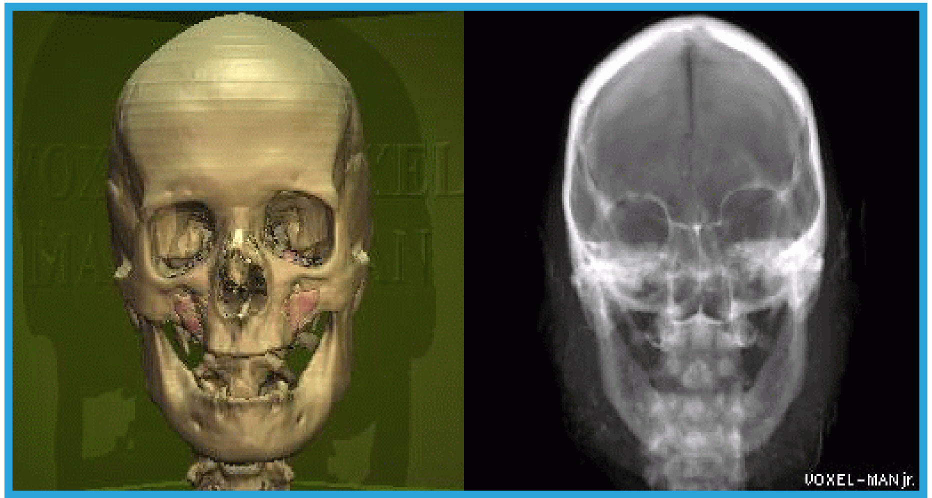


Visualization – Examples

- Medical data

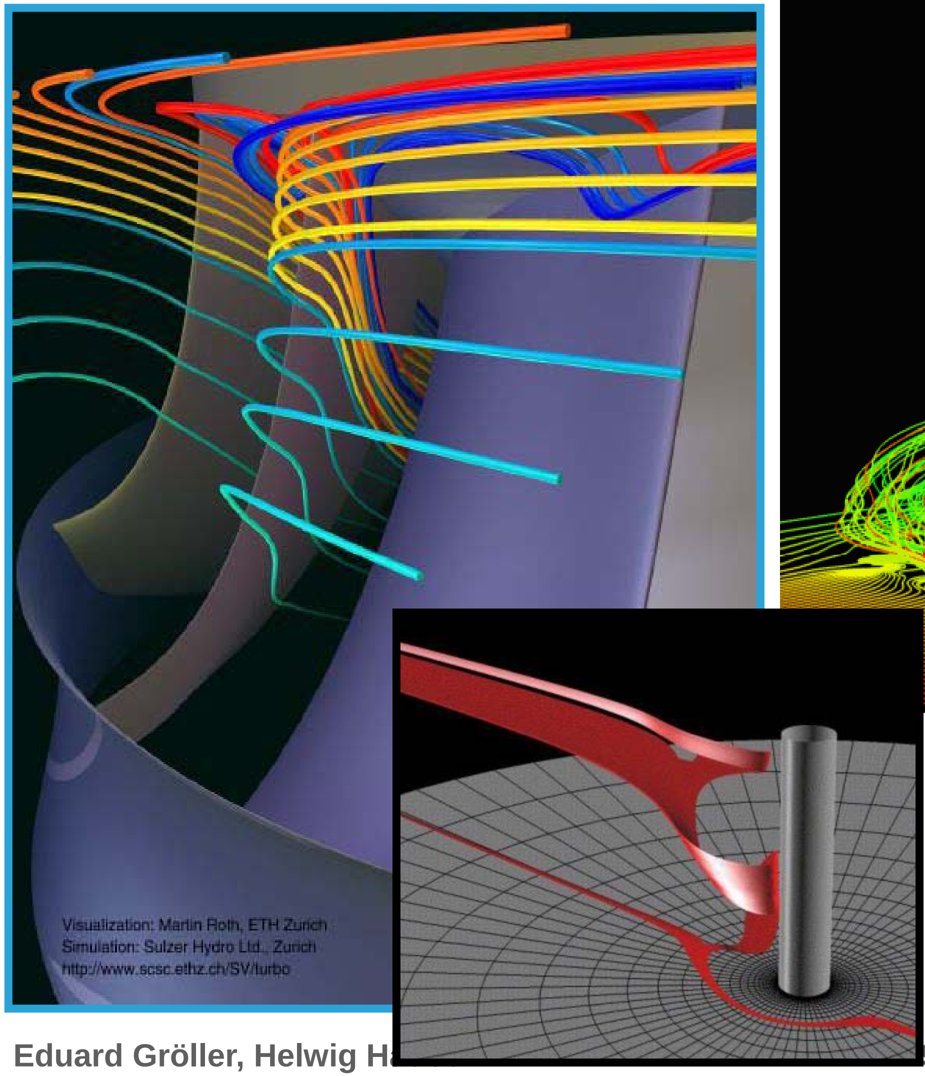


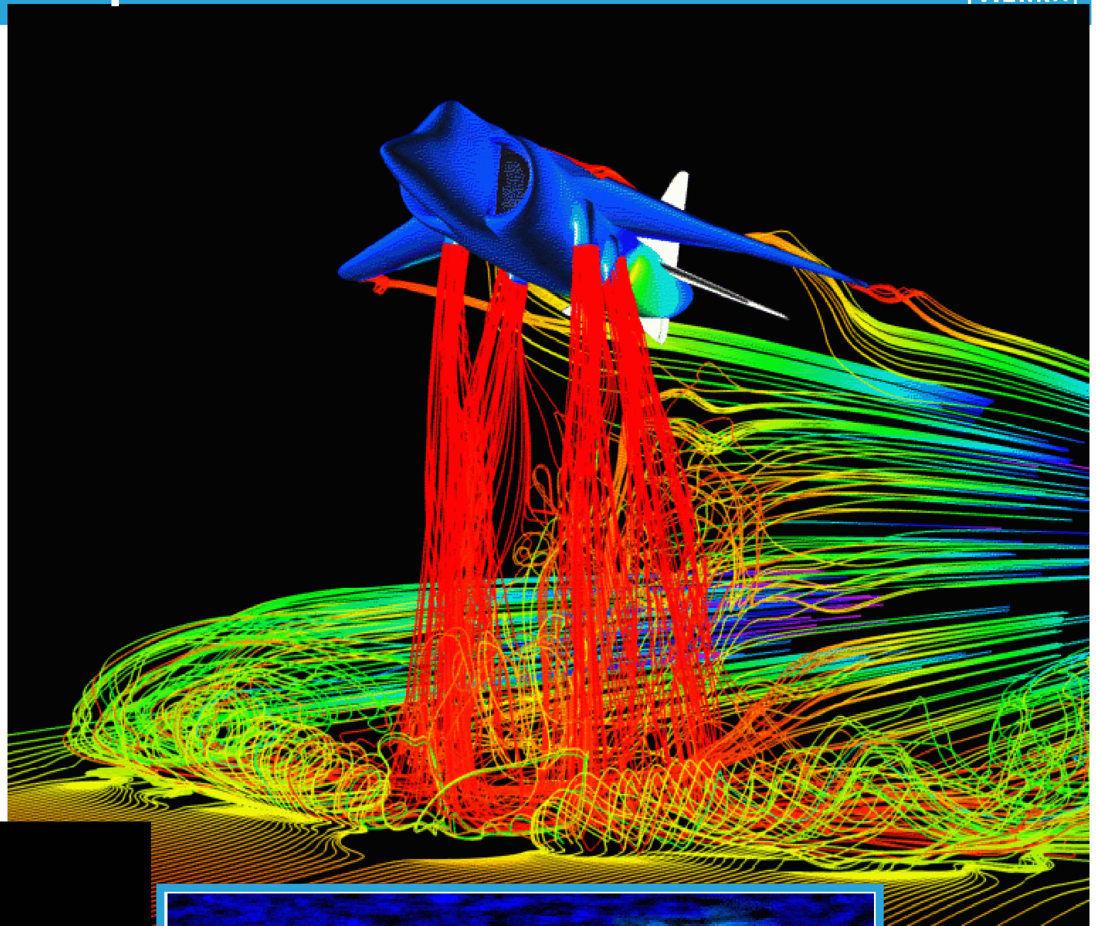


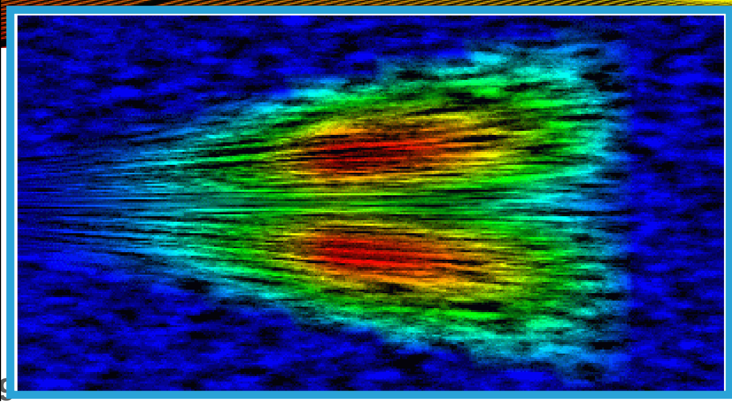


Visualization – Examples

- Flow data

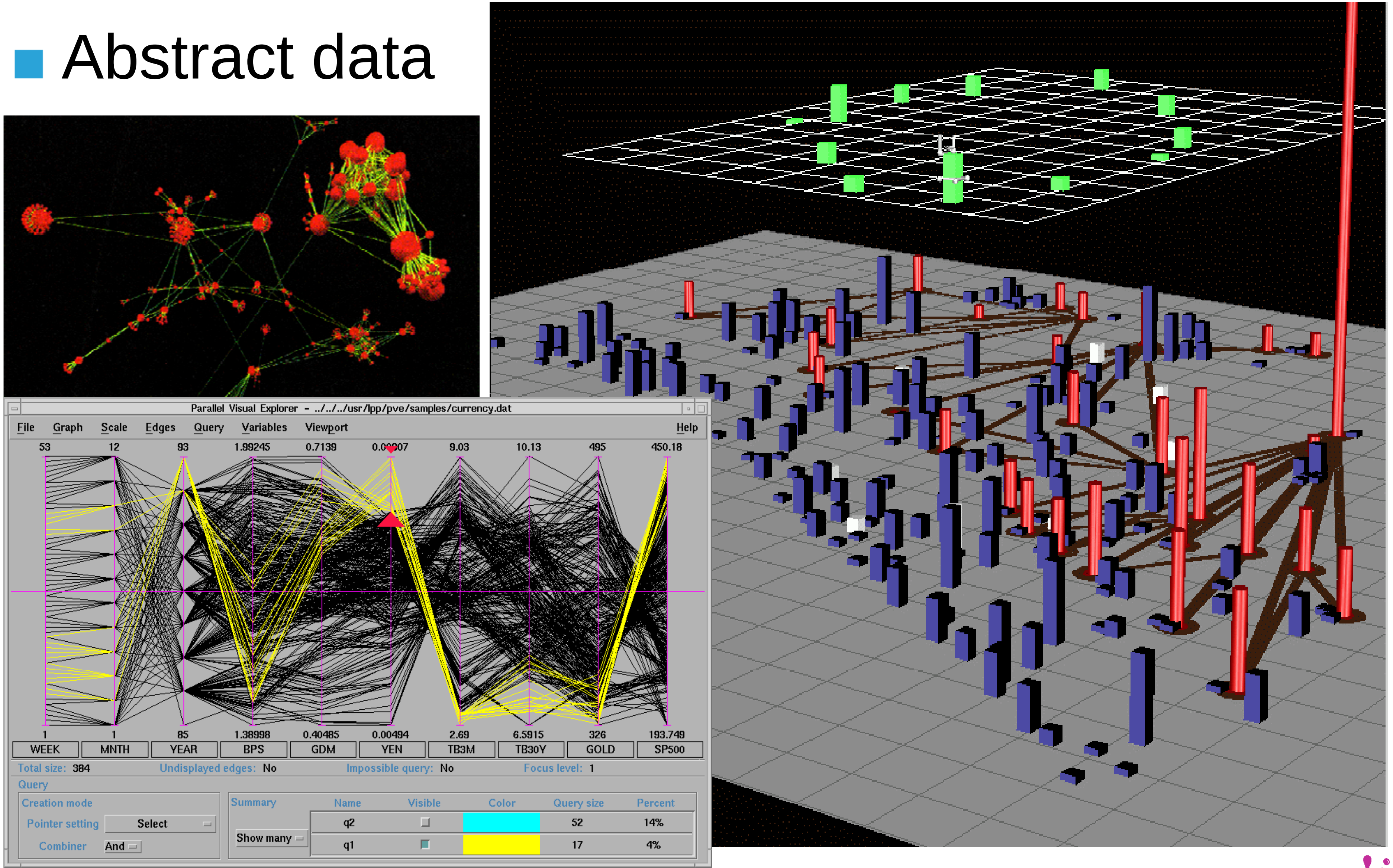






Visualization – Examples

- Abstract data



Visualization – Three Types of Goals

TU VIENNA

- Visualization, …
  - … to explore
    - Nothing is known,
      Vis. used for data exploration
  - … to analyze
    - There are hypotheses, ?!
      Vis. used for Verification or Falsification
  - … to present
    - “everything” known about the data, ?!
      Vis. used for Communication of Results

Visualization – Major Areas

- Major areas
  - Volume Visualization
  - Flow Visualization

  } Scientific Visualization

  Inherent spatial reference

  3D

  ---

  nD

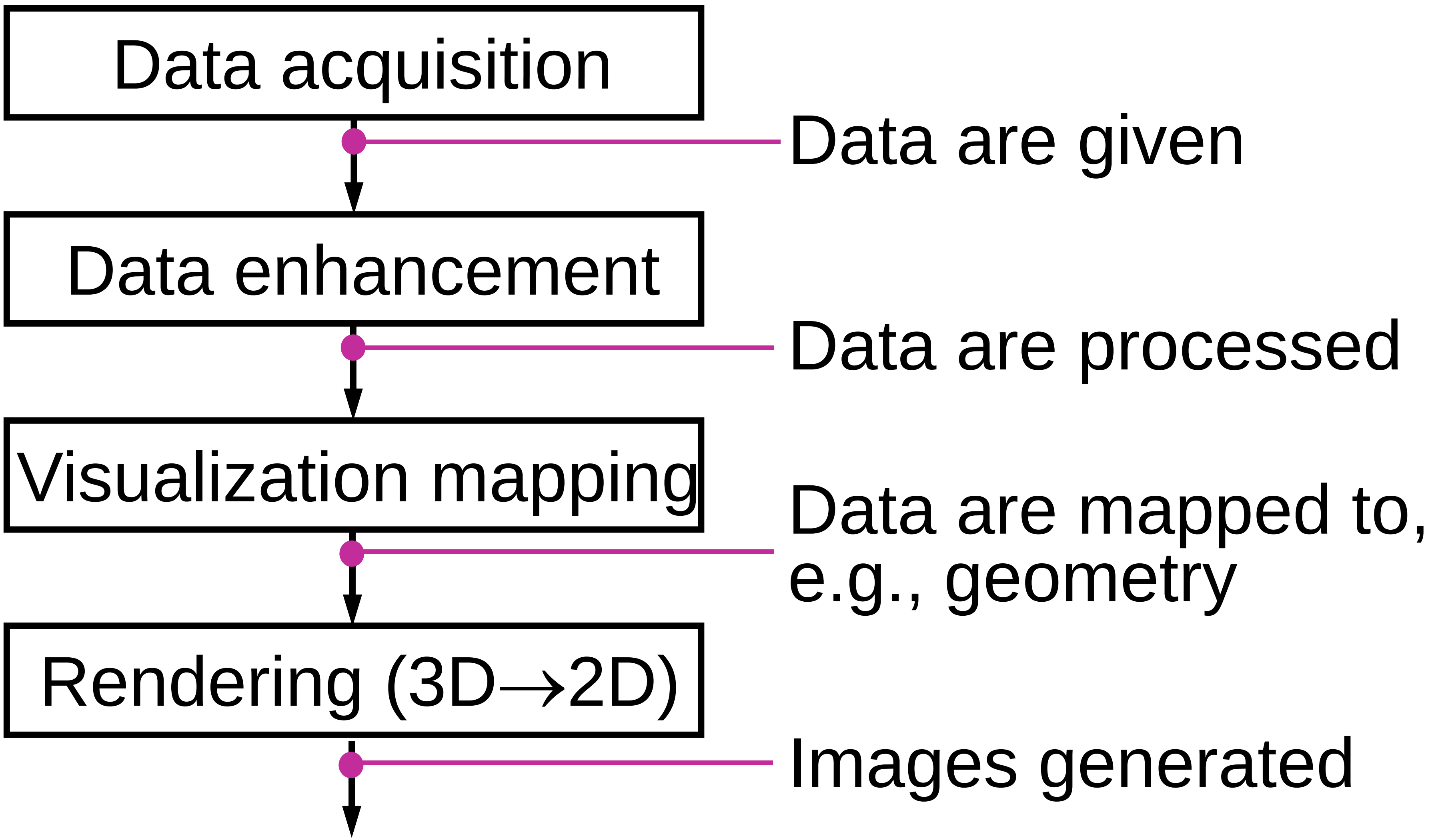
  - Information Visualization
  - Visual Analytics

  Usually no spatial reference

Visualization Pipeline

Typical steps in the visualization process

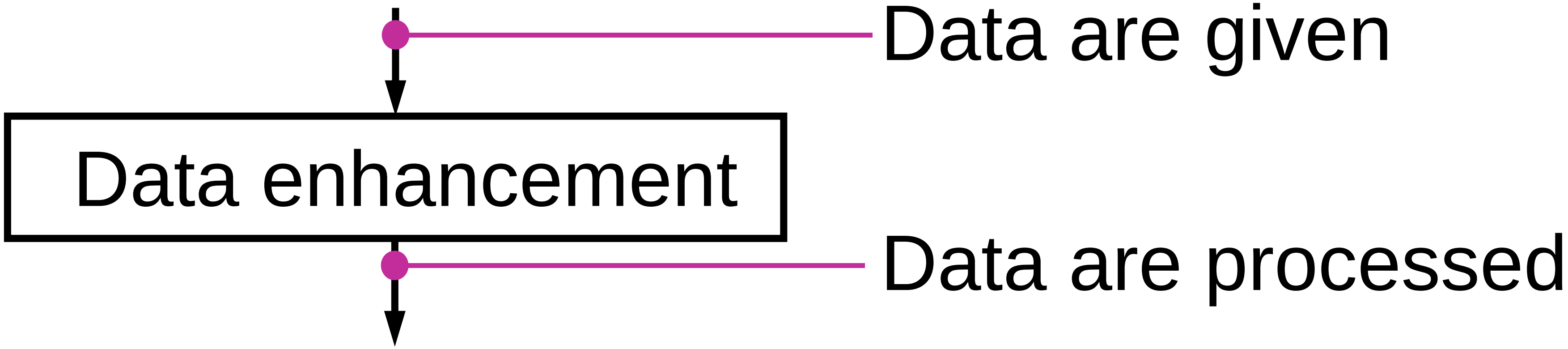
Visualization-Pipeline – Overview



Visualization-Pipeline – 1. Step

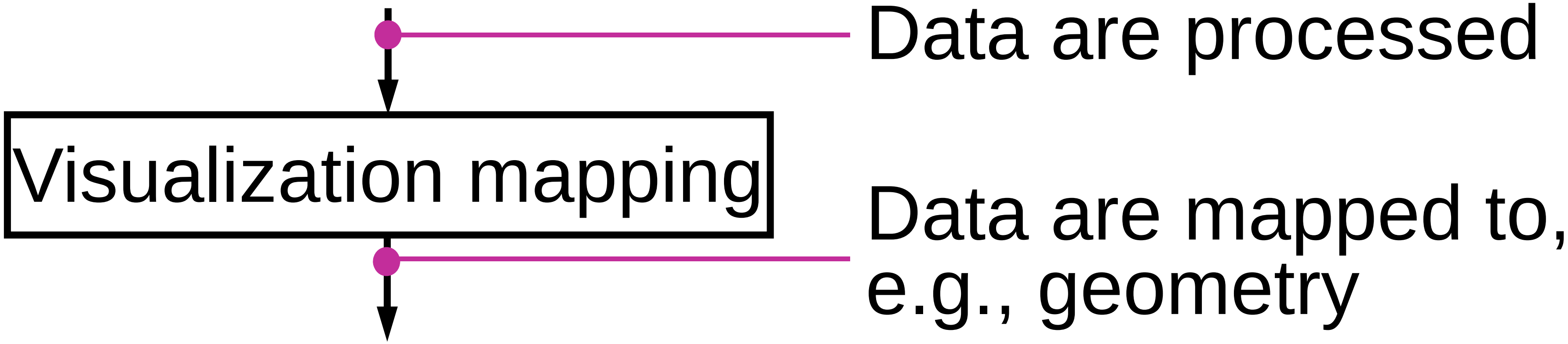
- Data acquisition
  - Measurements, e.g., CT/MRI
  - Simulation, e.g., flow simulation
  - Modelling, e.g., game theory

Visualization-Pipeline – 2. Step



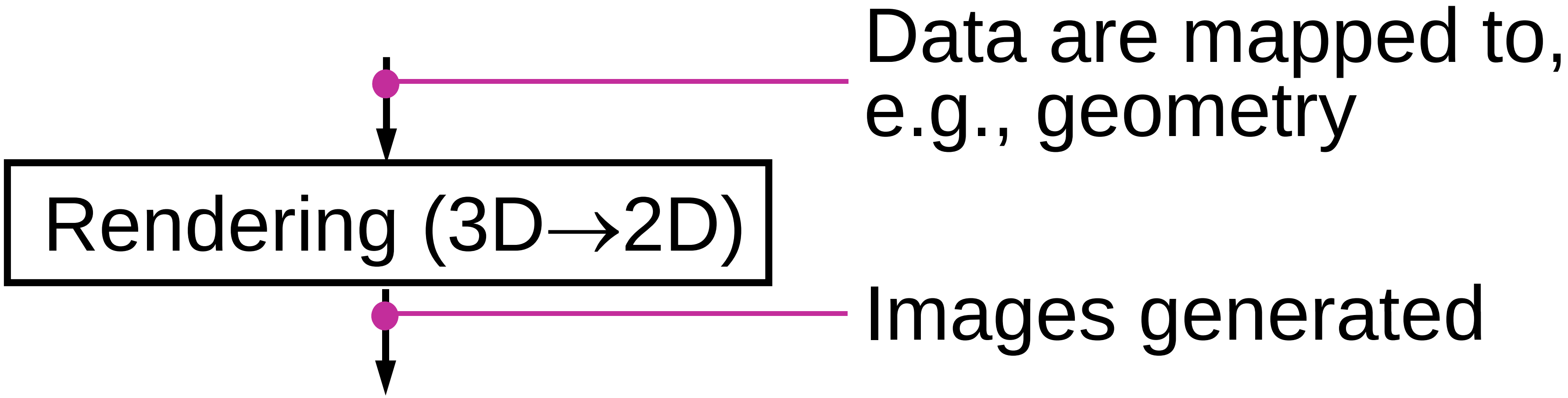
- Data enhancement
  - Filtering, e.g, smoothing (noise suppression)
  - Resampling, e.g., on a different-resolution grid
  - Data Derivation, e.g., gradients, curvature
  - Data interpolation, e.g., linear, cubic, …

Visualization-Pipeline – 3. Step

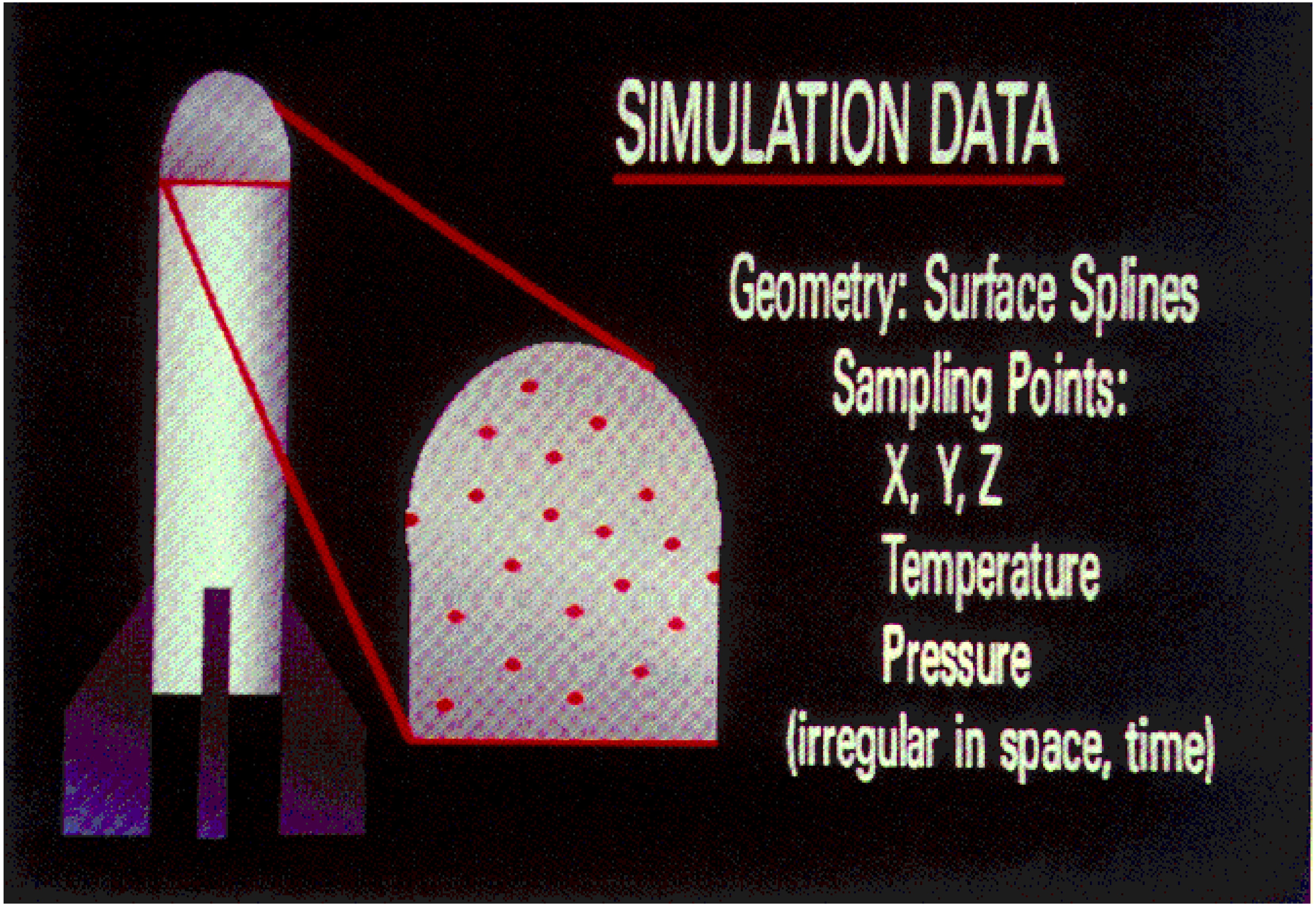


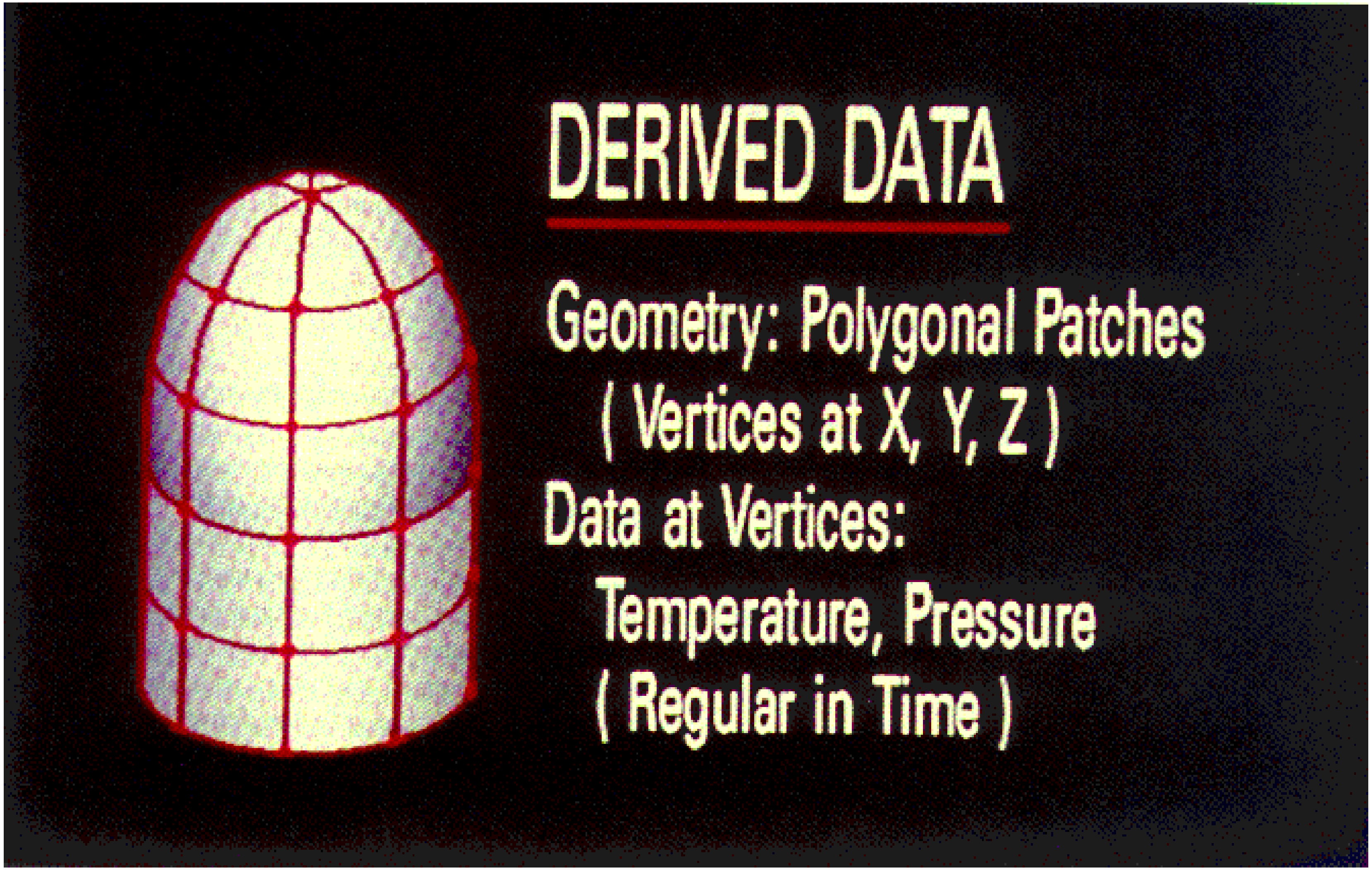
- Visualization mapping = data is renderable
  - Iso-surface calculation
  - Glyphs, Icons determination
  - Graph-Layout calculation
  - Voxel attributes: color, transparency, …

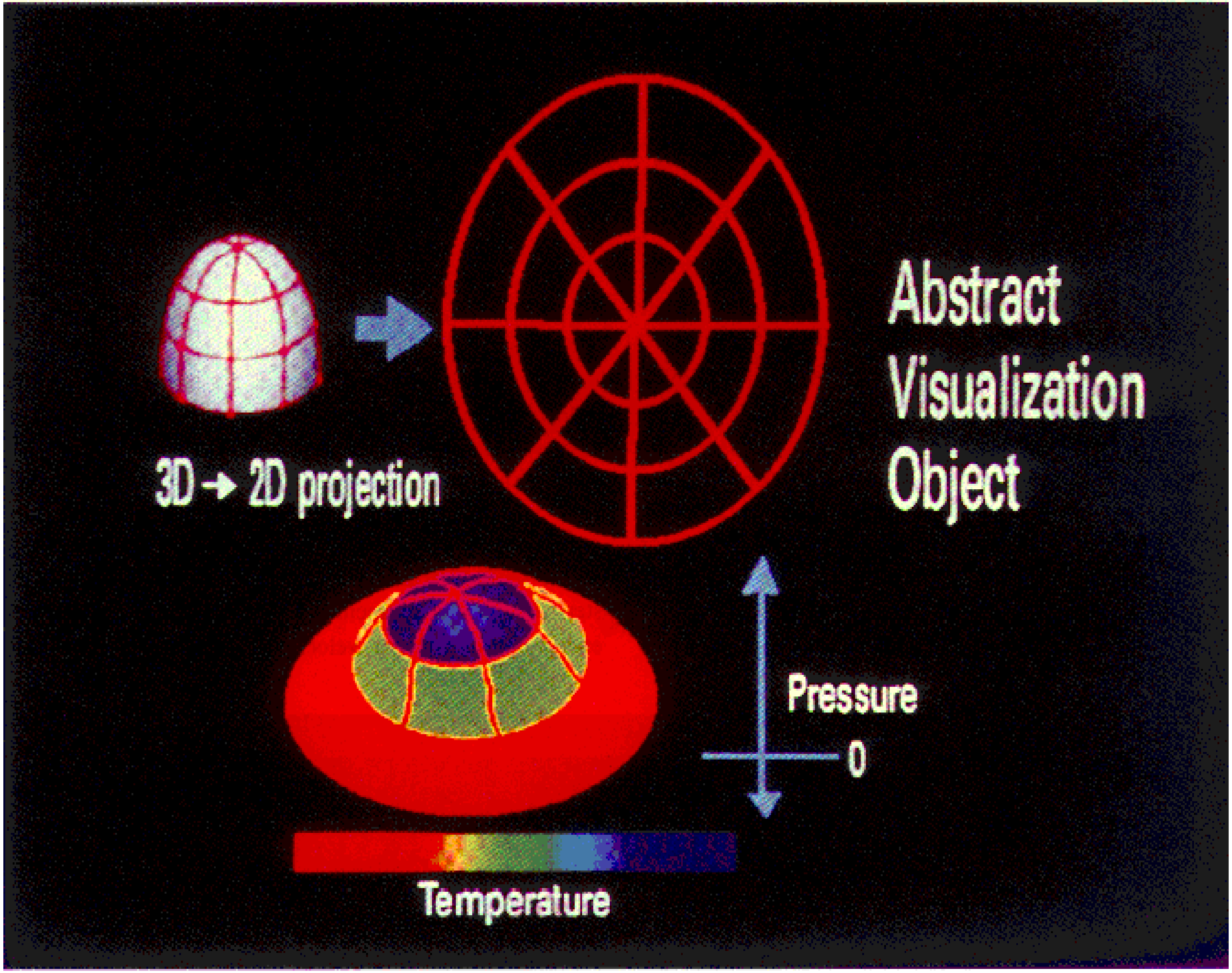
Visualization-Pipeline – 4. Step



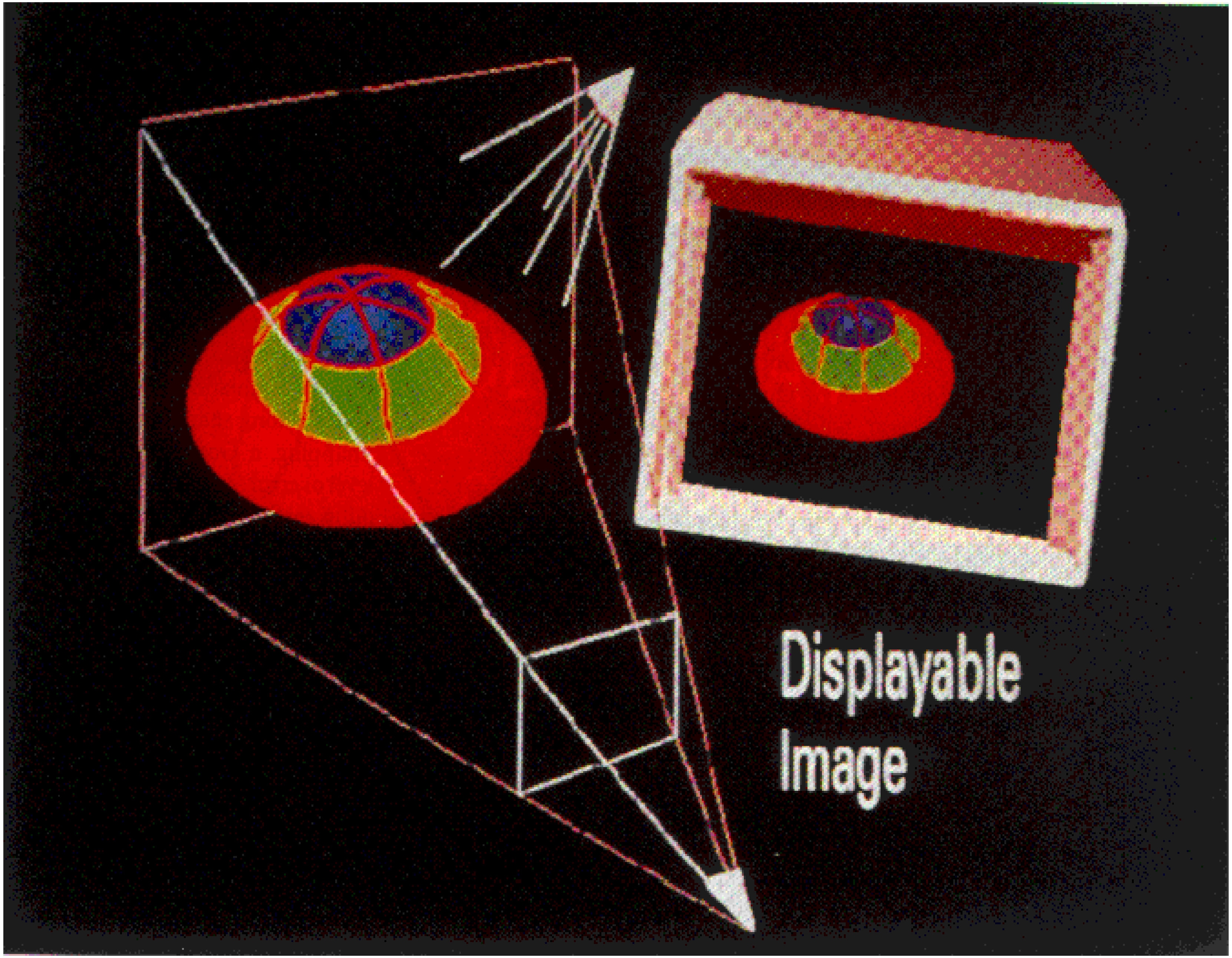
- Rendering = image generation with Computer Graphics
  - Visibility calculation
  - Illumination
  - Compositing (combine transparent objects, …)
  - Animation


SIMULATION DATA
Geometry: Surface Splines
Sampling Points:
X, Y, Z
Temperature
Pressure
(irregular in space, time)

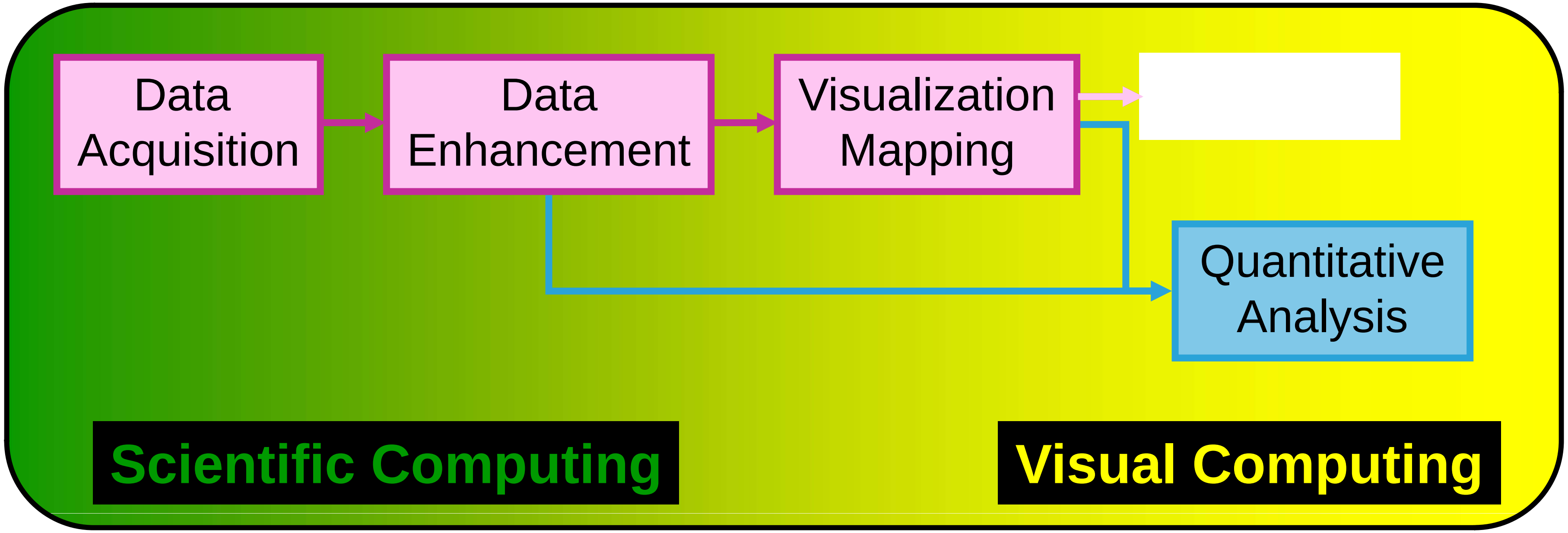

DERIVED DATA
Geometry: Polygonal Patches
(Vertices at X, Y, Z)
Data at Vertices:
Temperature, Pressure
(Regular in Time)



3D → 2D projection
Abstract
Visualization
Object
Pressure
0
Temperature


Displayable
Image

Computational Sciences



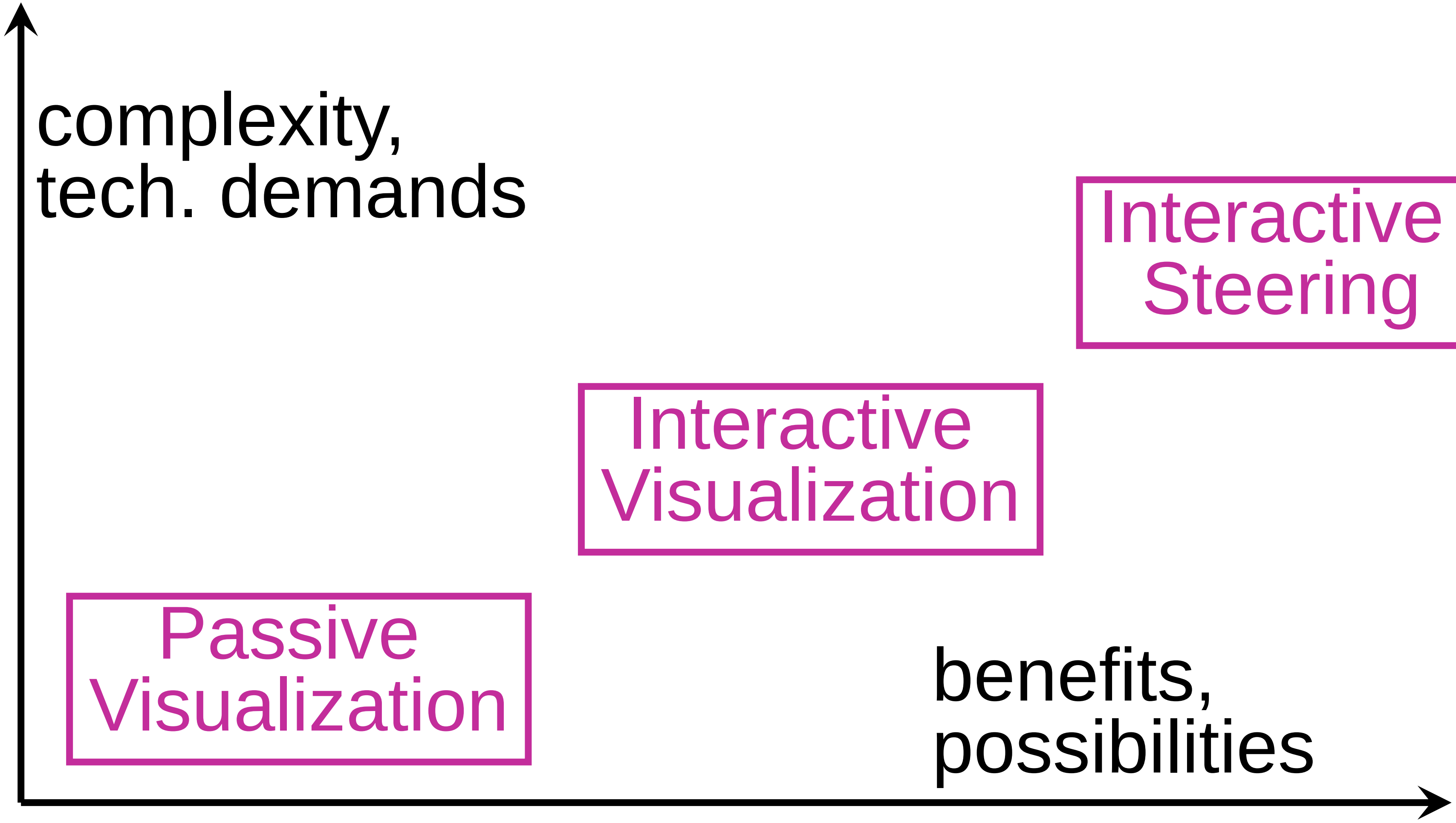
- Visual Computing
  - Scientific visualization
  - Computer vision
  - Human computer interaction

Visualization Scenarios

How closely is visualization connected to the data generation?

- Coupling varies considerably:
  - Data generation (data acquisition):
    - Measuring, Simulation, Modelling
    - Can take very long (measuring, simulation)
    - Can be very costly (simulation, modelling)
  - Visualization (rest of visualization pipeline):
    - Data enhancement, vis. mapping, rendering
    - Depending on computer, implementation: fast or slow
  - Interaction (user feedback):
    - How can the user intervene, vary parameters

Visualization Scenarios



On Data

Data characteristics,
Data attributes,
Data spaces

Data – General Information

- Data:
  - Focus of visualization,
    everything is centered around the data
  - Driving factor (besides user) in choice and attribution of the visualization technique
  - Important questions:
    - Where do the data "live" (**data space**)
    - **Type** of the data
    - Which **representation** makes sense (secondary aspect)

Data Space

- Where do the data "live"?
  - Inherent spatial domain (**SciVis**):
    - 2D/3D data space given
    - Examples: medical data, flow simulation data, GIS-data, etc.
  - No inherent spatial reference (**InfoVis**):
    - Abstract data,
      spatial embedding through visualization
    - Example: data bases
  - **Aspects**: dimensionality (data space), coordinates, region of influence (local, global), domain

Data Characteristics

- What type of data?
  - **Data types**:
    - Scalar = numerical value (natural, whole, rational, real, complex numbers)
    - Non numerical (nominal, ordinal values)
    - Multidimensional values (n-dim. vectors, n×n-dim. tensors of data from same type)
    - Multimodal values (vectors of data with varying type [e.g., row in a table])
  - **Aspects**: dimensionality, co-domain (range)

Data Representation

- How can data be represented?
  - inherent spatial domain?
    - Yes $\Rightarrow$ Recycle data space? Or not?
    - No $\Rightarrow$ Select which representation space?
  - Which dimension is used what for?
    - Relationship data space $\Leftrightarrow$ data characteristics
    - Available display space (2D/3D)
    - Where is the focus?
    - Where can you abstract / save (e.g., too many dimensions)

Data Space vs. Data characteristics

	1D	2D	3D
1D	y=f(x)		Spatial Curve **x**(t)
2D		2D-Flow **v**(**x**)	
3D	CT-data d(**x**)		

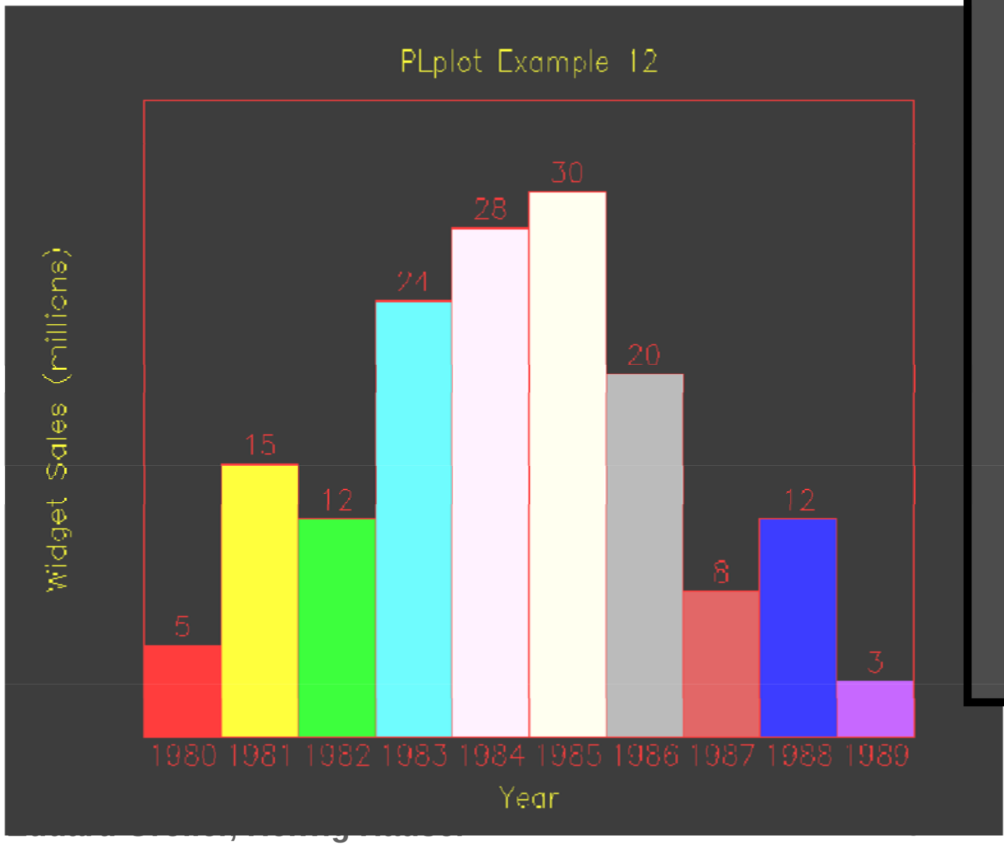
Examples

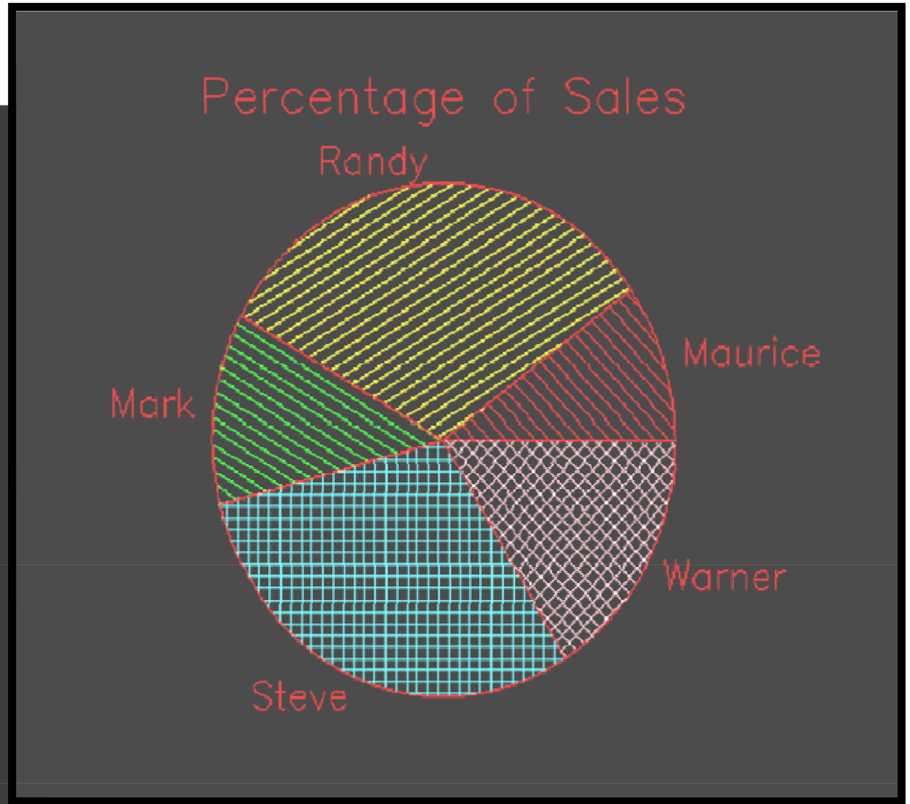
Visualization Examples

data	description	visualization example
$N^1 \rightarrow R^1$	value series	bar chart, pie chart, etc.
$R^1 \rightarrow R^1$	function	(line) graph
$R^2 \rightarrow R^1$	function over R^2	2D-height map in 3D, contour lines in 2D, false color map
$N^2 \rightarrow R^2$	2D-vector field	hedgehog plot, LIC, streamlets, etc.
$R^3 \rightarrow R^1$	3D-densities	iso-surfaces in 3D, volume rendering
$(N^1 \rightarrow) R^n$	set of tuples	parallel coordinates, glyphs, icons, etc.

Visualization Examples

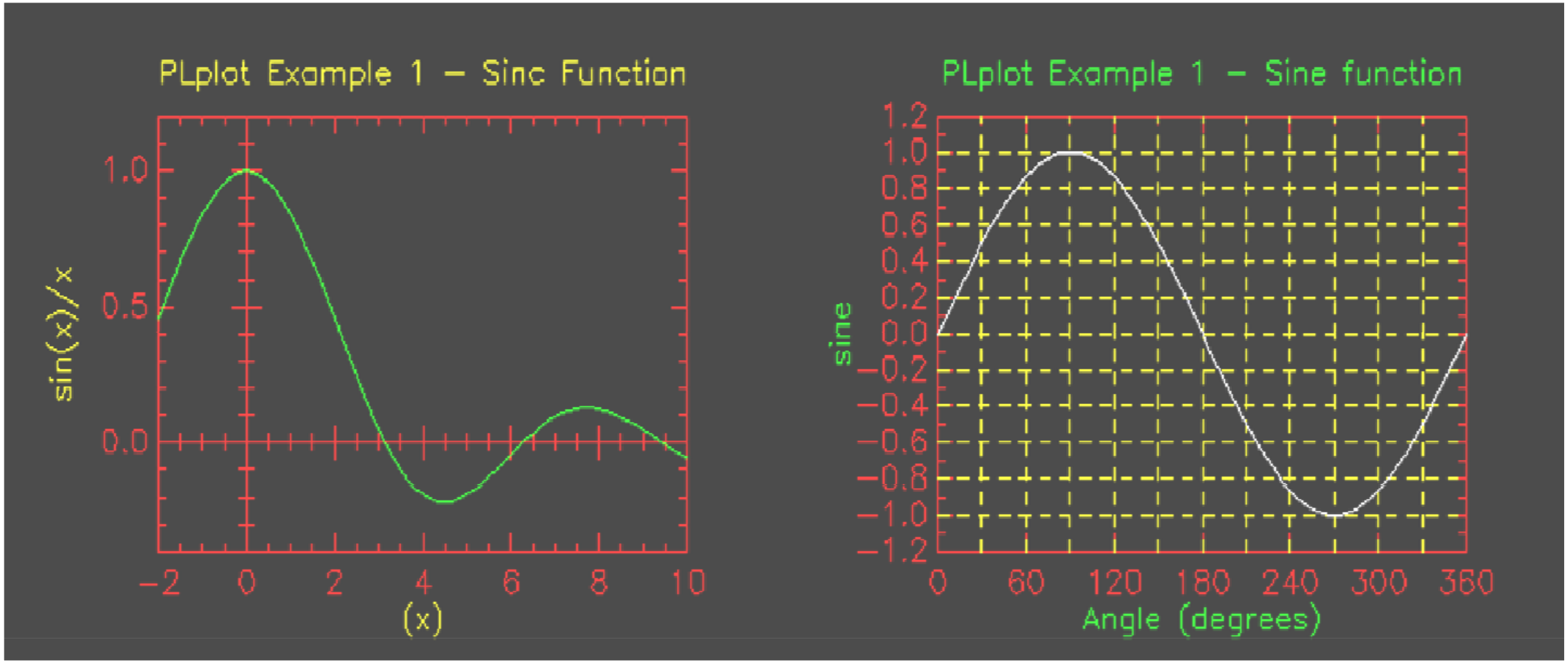
data	description	visualization example
$N^1 \rightarrow R^1$	value series	bar chart, pie chart, etc.





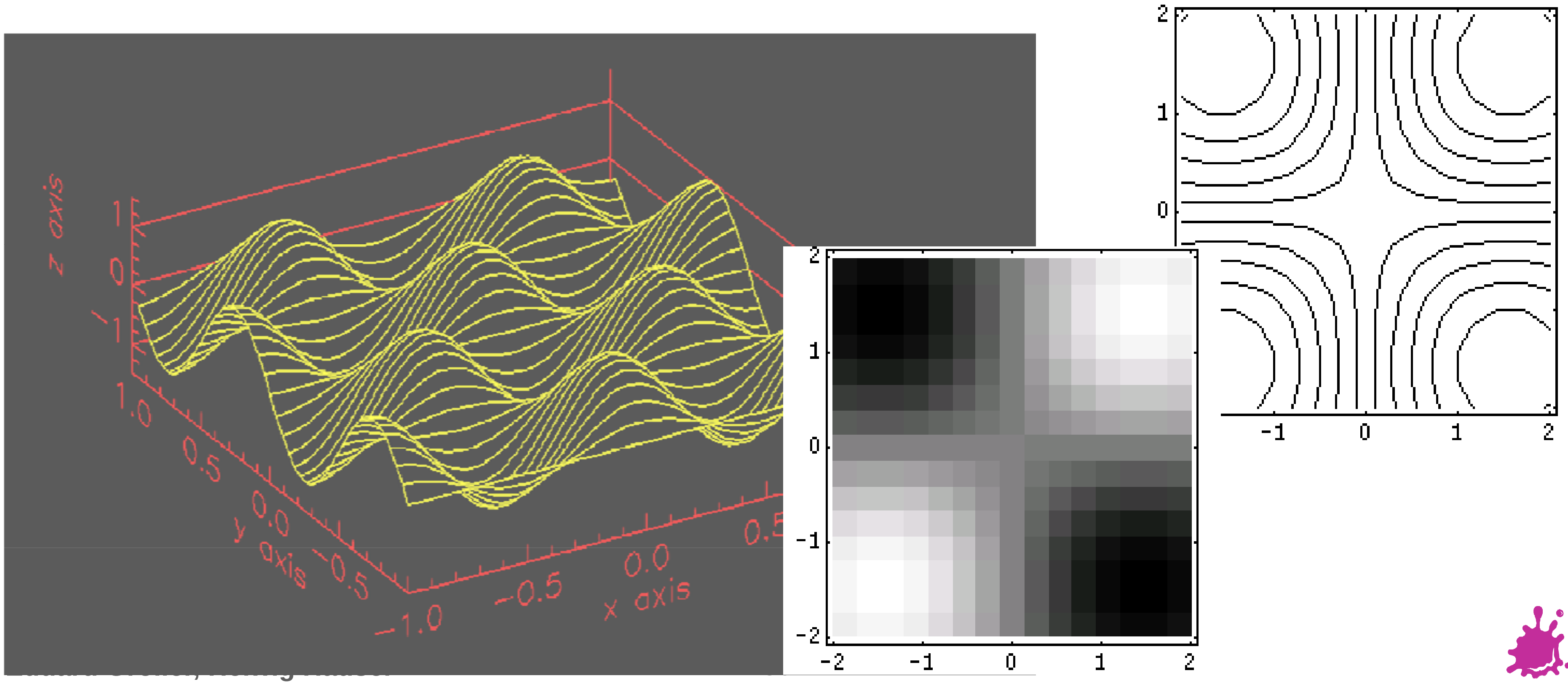
Visualization Examples

data	description	visualization example
$R^1 \rightarrow R^1$	function	(line) graph



Visualization Examples

data	description	visualization example
$R^2 \rightarrow R^1$	function over R^2	2D-height map in 3D, contour lines in 2D, false color map



Visualization Examples

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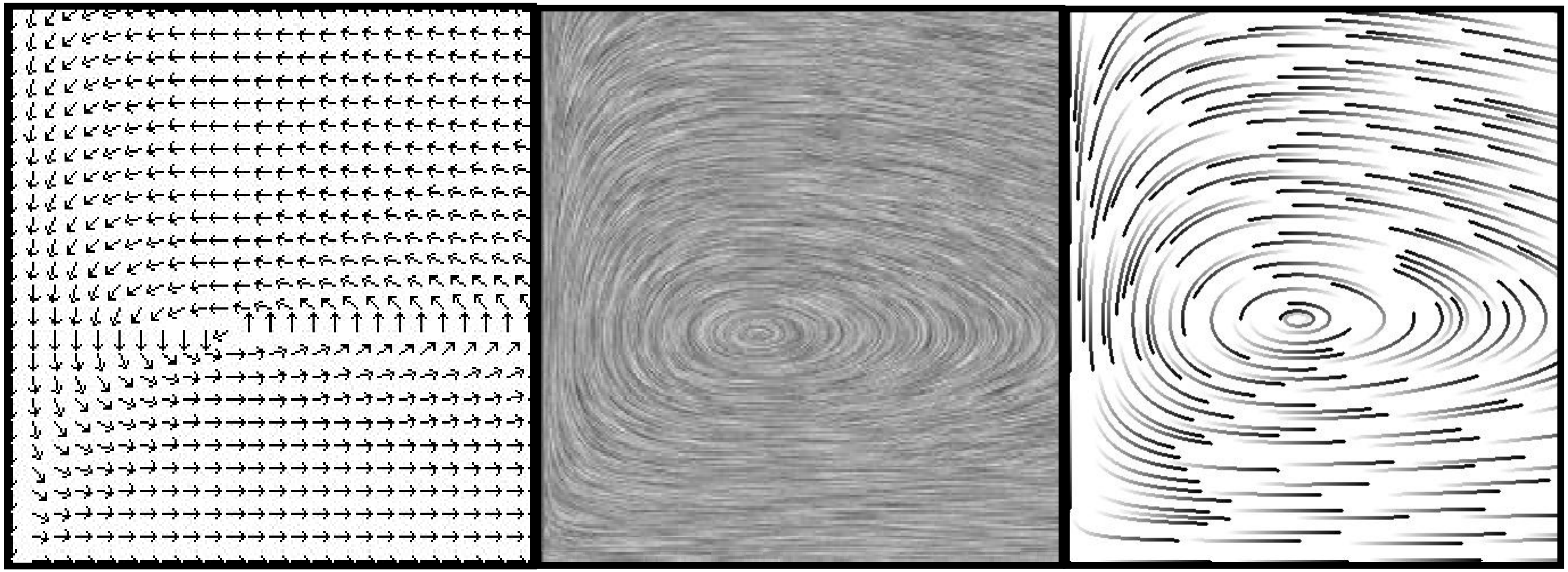
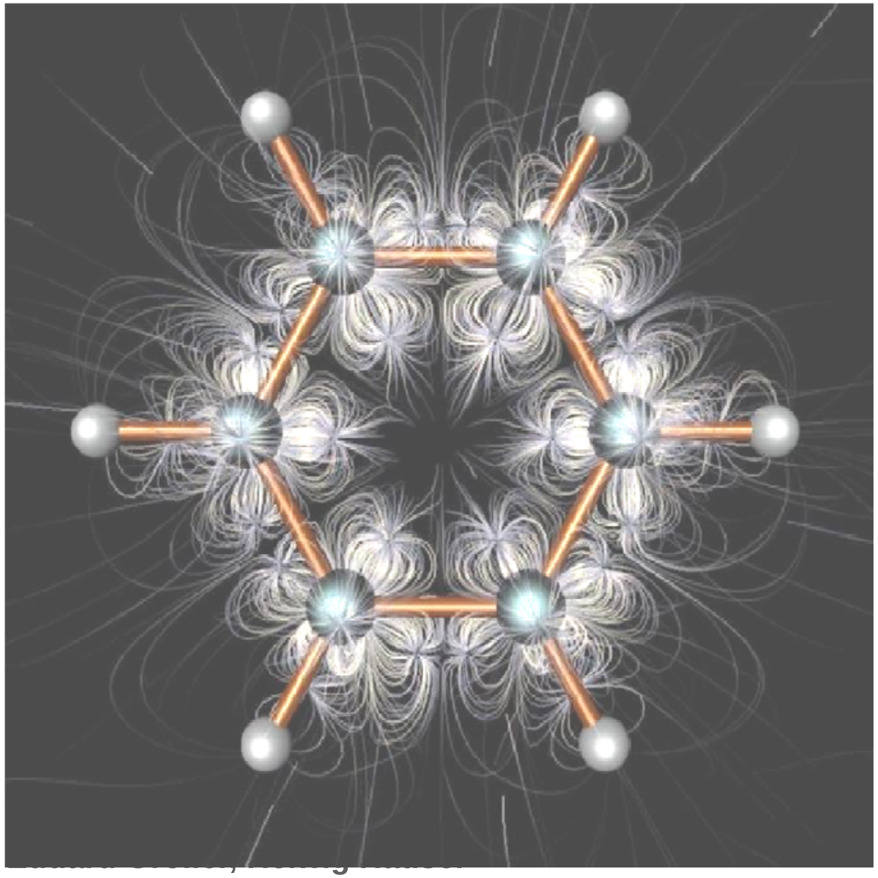
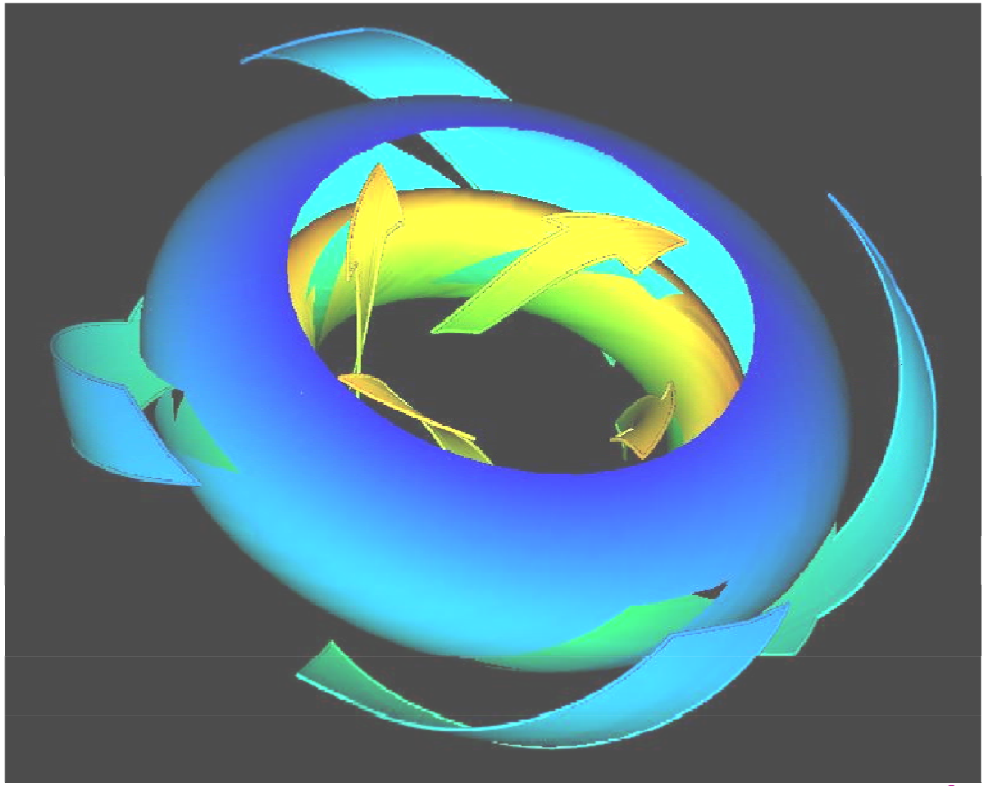
$N^2 \rightarrow R^2$	2D-vector field	hedgehog plot, LIC, streamlets, etc



Visualization Examples

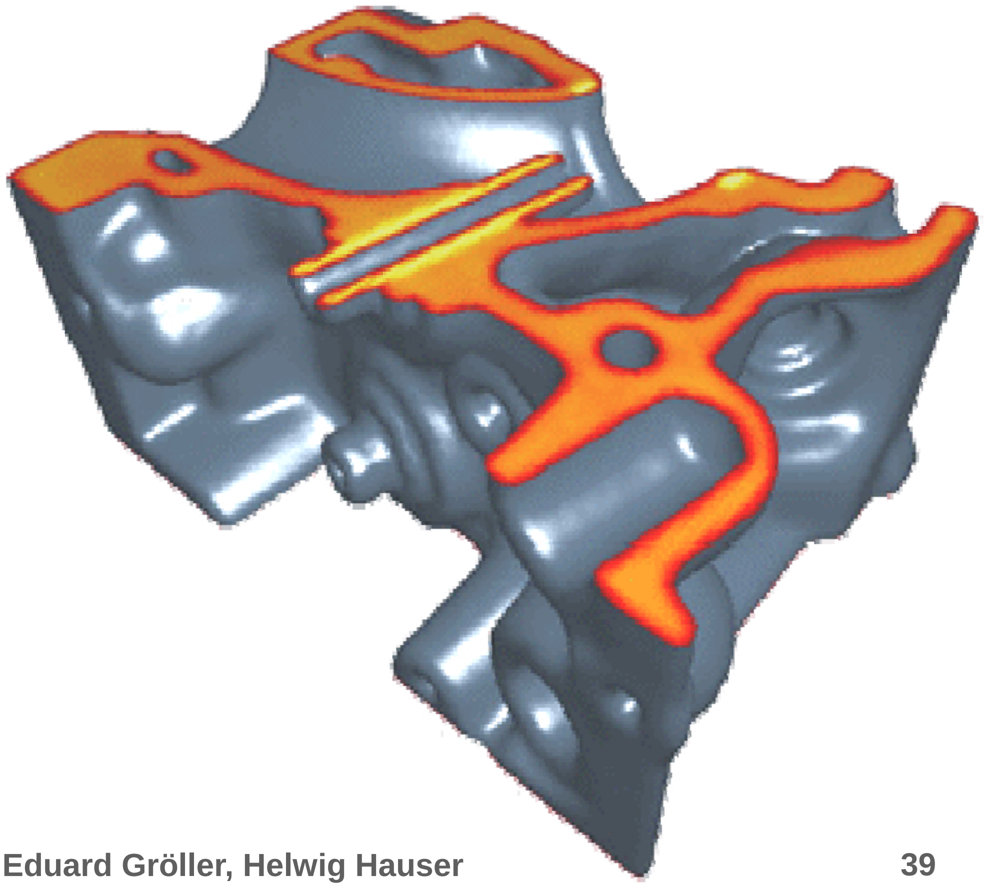
	data	description	visualization example
■	$R^3 \rightarrow R^3$	3D-flow	streamlines, streamsurfaces

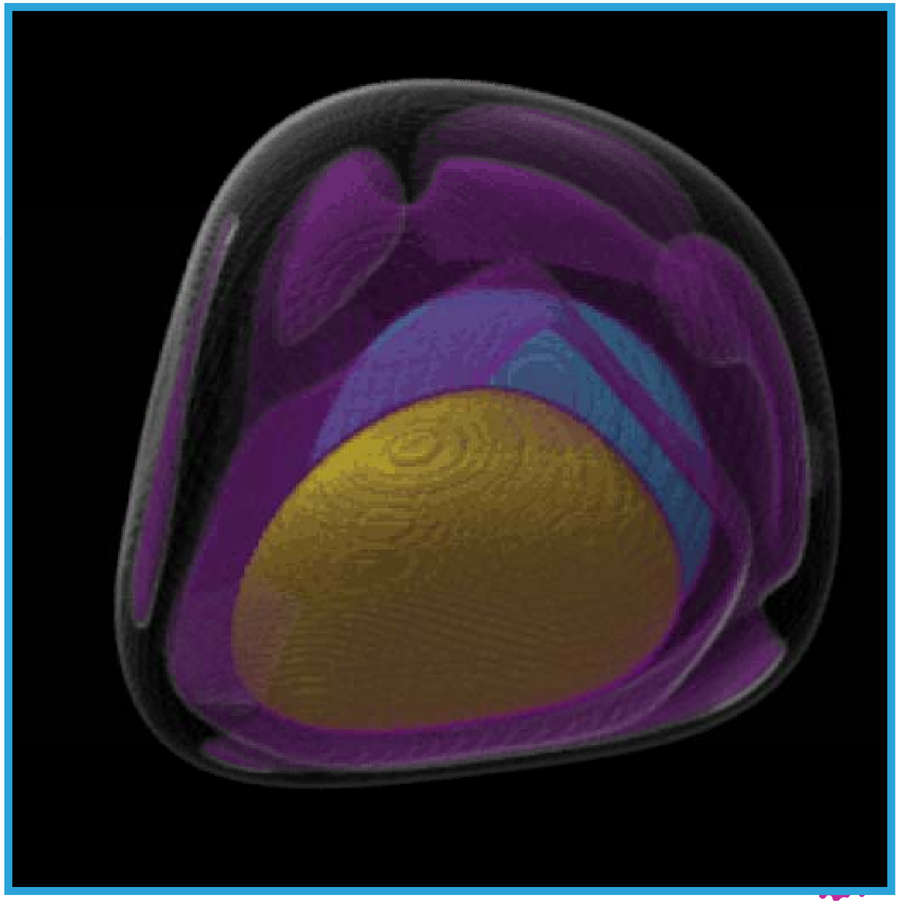




Visualization Examples

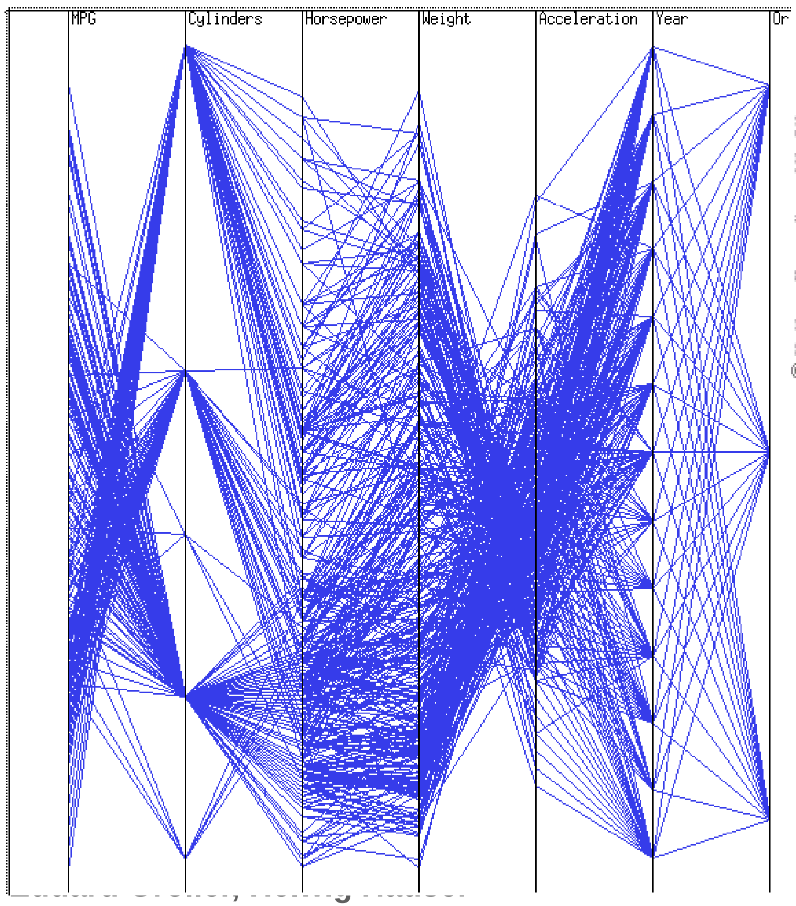
data	description	visualization example
$R^3 \rightarrow R^1$	3D-densities	iso-surfaces in 3D, volume rendering

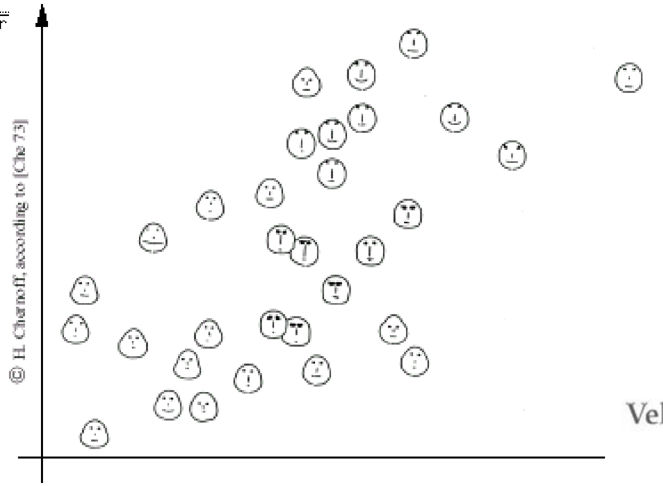


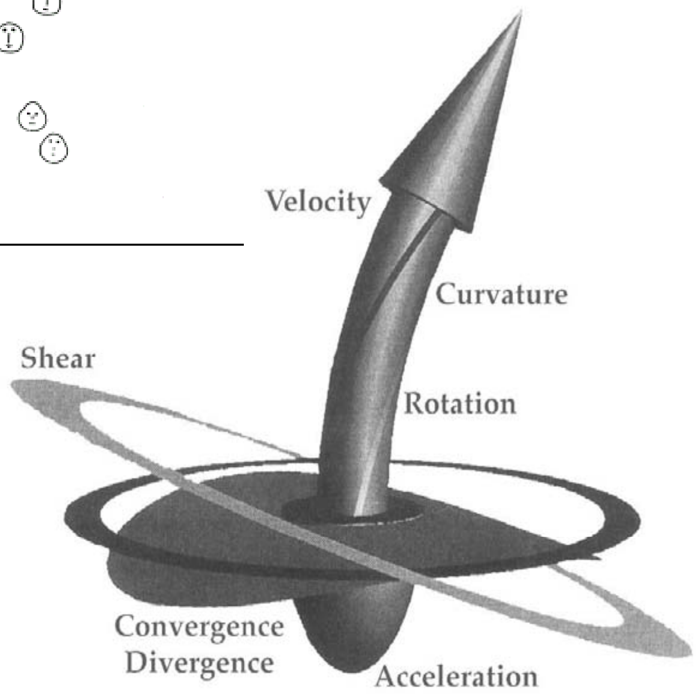


Visualization Examples

data	description	visualization example
$(N^1 \to)R^n$	set of tuples	parallel coordinates, glyphs, icons, etc.







On Grids

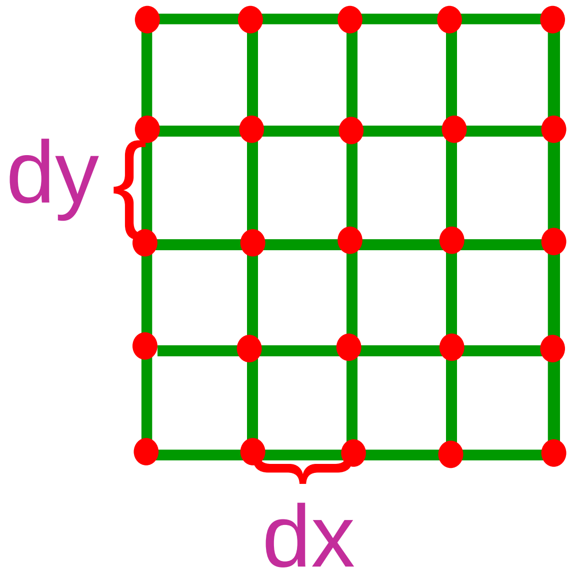
On the organisation of sampled data

Grids – General Information

- Important questions:
  - Which data organisation is optimal?
  - Where do the data come from?
  - Is there a neighborhood relationship?
  - How is the neighborhood info. stored?
  - How is navigation within the data possible?
  - Calculations with the data possible ?
  - Are the data structured?

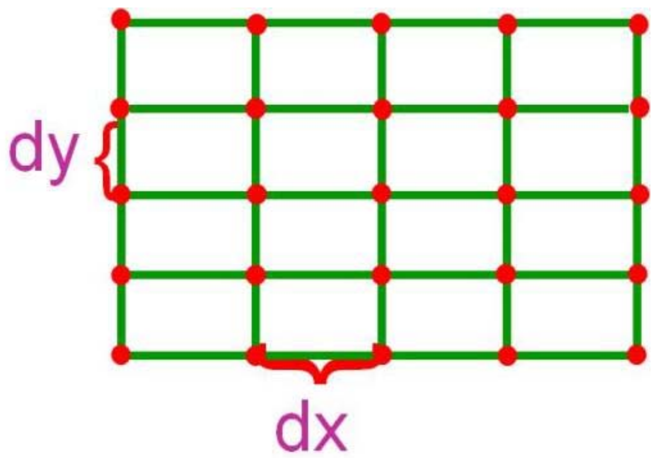
Cartesian Grid

- Characteristics:
  - Orthogonal, equidistant grid
  - Uniform distances (in all dims., dx=dy)
  - Implicit neighborhood-relationship (cf. array of arrays)

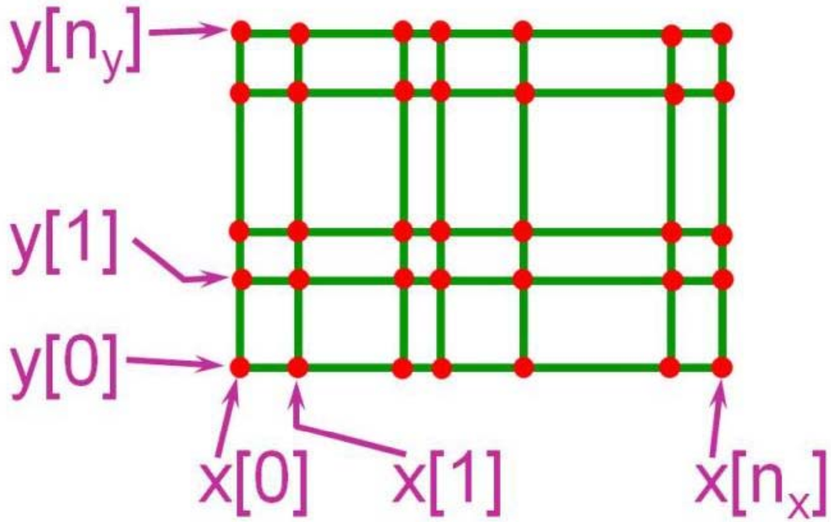


Regular Grid – Rectilinear Grid

- Regular Grid
  - dx≠dy

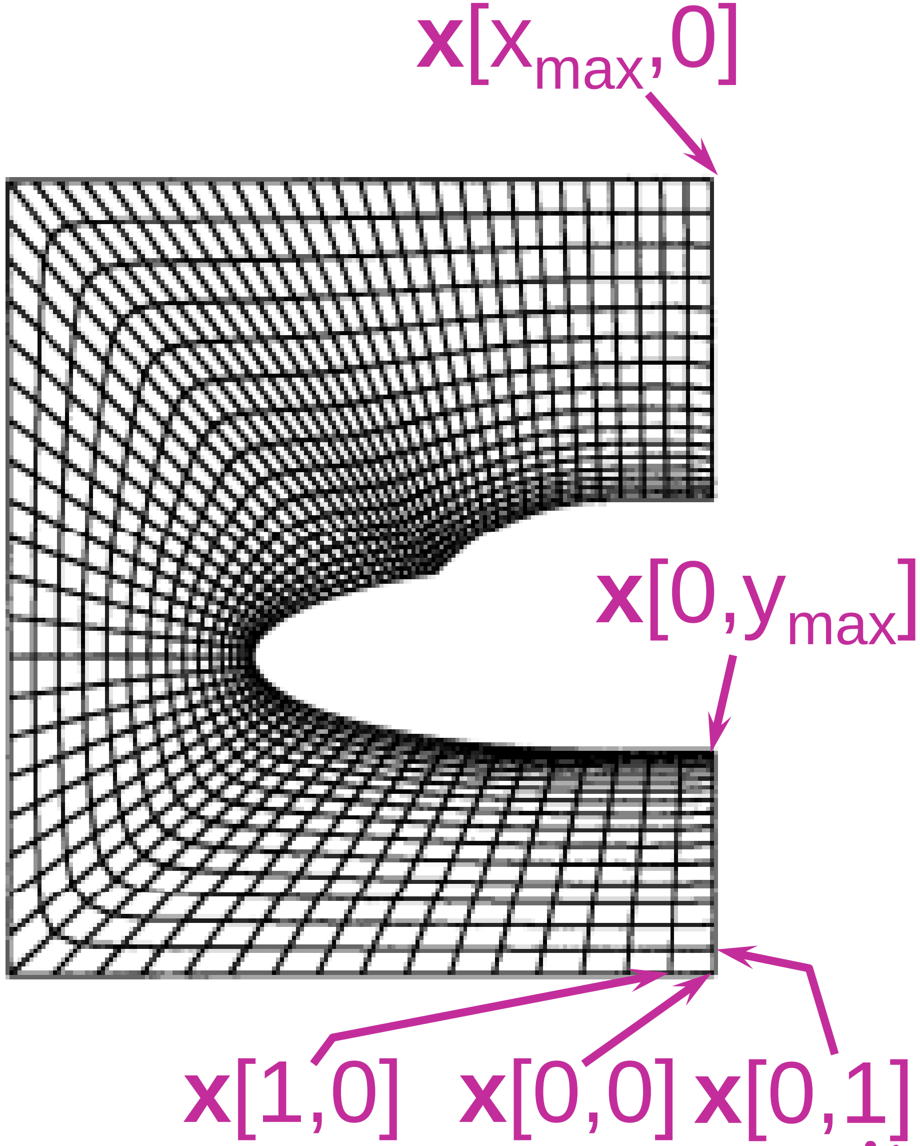


- Rectilinear Grid
  - varying sample-distances x[i], y[j]



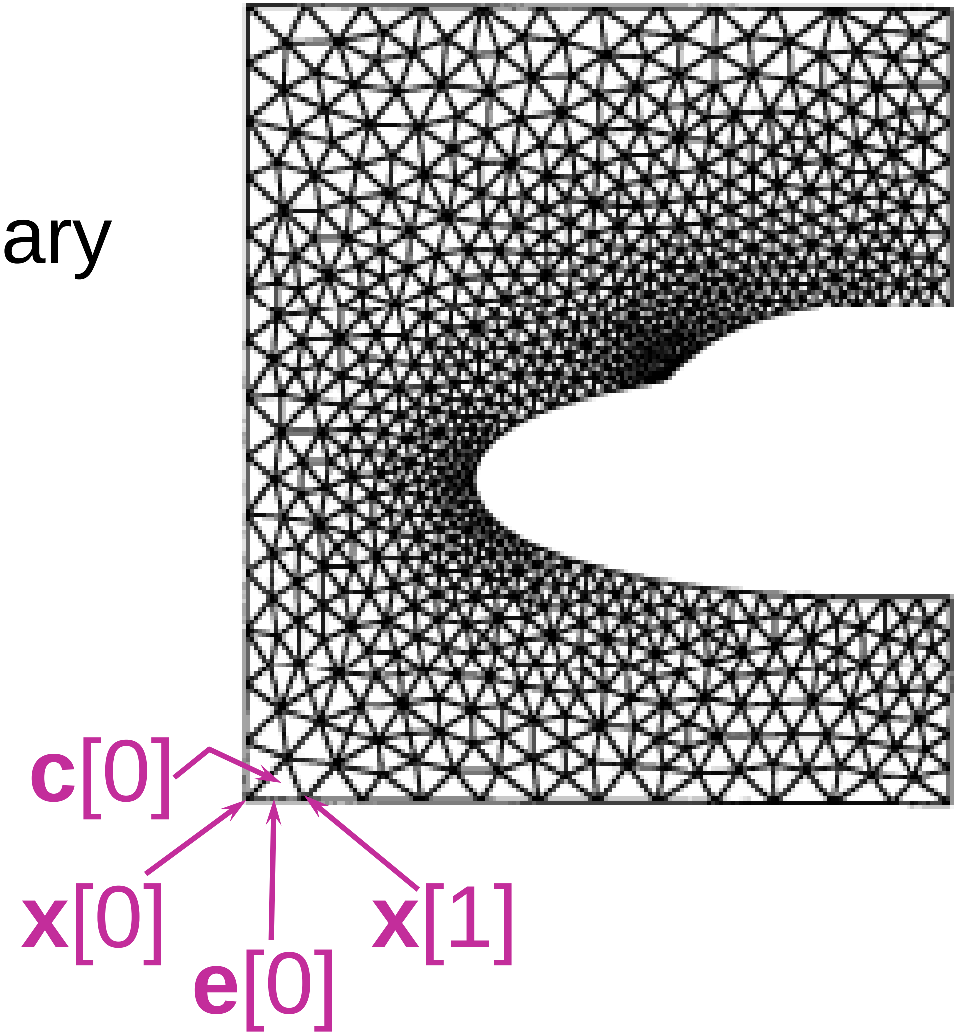
Curvilinear Grid

- Characteristics:
  - non-orthogonal grid
  - grid-points explicitely given (**x**[i,j])
  - Implicit neighborhood-relationship

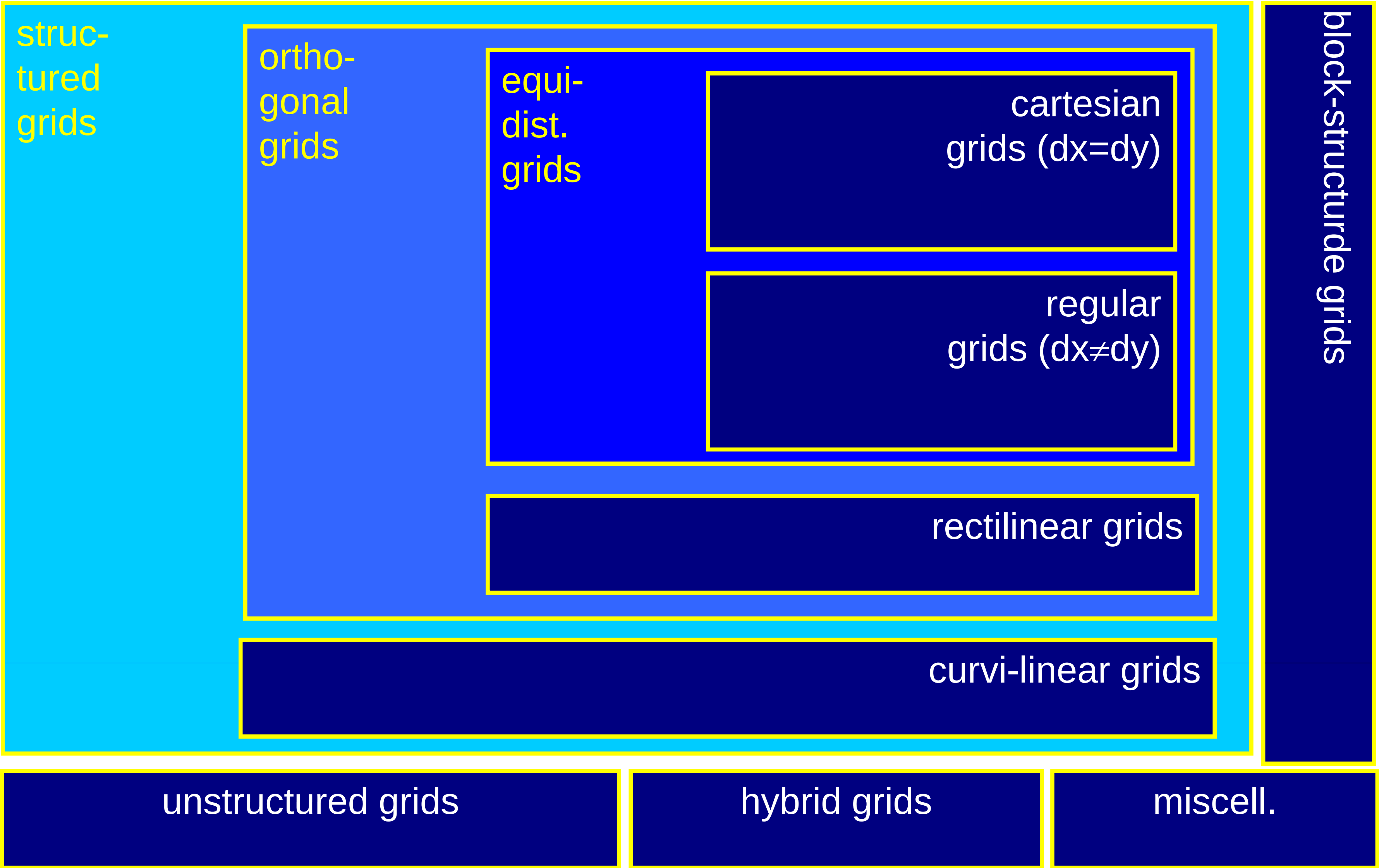


Unstructured Grid

- Characteristics:
  - Grid-points and connections arbitrary
  - Grid-points and neighborhood explicitly given
  - Cells: tetrahedra, hexahedra

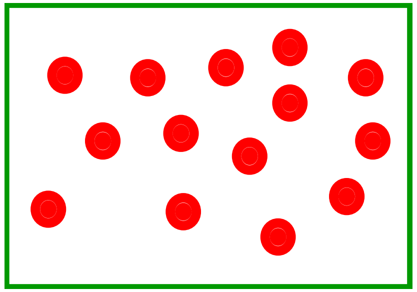


Grids - Survey



Scattered Data

- Characteristics:
  - Grid-free data
  - Data points given without neighborhood-relationship
  - Influence on neighborhood defined by spatial proximity
  - Scattered data interpolation



Grid Transformations

- Conversion between grids:
  - physical domain (simulation)
  - computational domain (visualization mapping)
  - image domain (rendering)
  - etc.
- Questions:
  - Accuracy of re-sampling!
  - Design of algorithms

Visualization and Color

Guidelines for the Usage of
Color in Visualization

Usage of Color

- Some facts:
  - Color can emphasize information
  - Number of colors only 7±2
  - Appr. 50–300 shades distinguishable (different for different colors)
  - Rainbow color scale ≠ linear!
  - Color perception strongly depends on context
  - Color blind users are handicapped
  - Observe color associations

Guidelines for Usage of Color

- Desaturated lines as border of colored areas
- No saturated blue for details, animations
- do not mix saturated blue and red
  (why? therefore)
- Avoid high color frequencies
- Colors to compare should be close
- Observe context, associations!
- Well suited: color for qualitative visualization
- Use redundancy (shape, style, etc.)