Visualisierung 1
2015W, VU, 2.0h, 3.0EC 186.827

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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**


- **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 25 years
  - First dedicated conferences: 1990

L. da Vinci (1452-1519)
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 (astronomy)
  - Extrem large data sets
  etc. …
Visualization – Examples

- Medical data
Visualization – Examples

Flow data

Visualization: Martin Rehn, ETH Zurich
Simulation: Sulzer Hydro Ltd., Zurich
http://www.srsc.ethz.ch/SV/turb
Visualization – Examples

■ Abstract data
Visualization – Three Types of Goals

- 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
  - Information Visualization
  - Visual Analytics

Scientific Visualization

Inherent spatial reference

3D

nD

Usually no spatial reference
Visualization Pipeline

Typical steps in the visualization process
Visualization-Pipeline – Overview

Data acquisition

Data are given

Data enhancement

Data are processed

Visualization mapping

Data are mapped to, e.g., geometry

Rendering (3D→2D)

Images generated
Visualization-Pipeline – 1. Step

Data acquisition

- Data are given

- Data acquisition
  - Measurements, e.g., CT/MRI
  - Simulation, e.g., flow simulation
  - Modelling, e.g., game theory
Visualization-Pipeline – 2. Step

Data enhancement

Data are given

Data are processed

- 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 are processed
  Data are mapped to, e.g., geometry

- Visualization mapping = data is renderable
  - Iso-surface calculation
  - Glyphs, Icons determination
  - Graph-Layout calculation
  - Voxel attributes: color, transparency, …
Visualization-Pipeline – 4. Step

Rendering (3D→2D)

Data are mapped to, e.g., geometry

Images generated

- 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 )
Displayable Image
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

Complexity, tech. demands

Passive Visualization

Interactive Visualization

Interactive Steering

Benefits, possibilities
On Data

Data characteristics,
Data attributes,
Data spaces
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
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)
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

<table>
<thead>
<tr>
<th></th>
<th>1D</th>
<th>2D</th>
<th>3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1D</td>
<td>y = f(x)</td>
<td>Spatial Curve (x(t))</td>
<td></td>
</tr>
<tr>
<td>2D</td>
<td></td>
<td>2D-Flow (v(x))</td>
<td></td>
</tr>
<tr>
<td>3D</td>
<td>CT-data (d(x))</td>
<td></td>
<td>Examples</td>
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## Visualization Examples

<table>
<thead>
<tr>
<th>data</th>
<th>description</th>
<th>visualization example</th>
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<tbody>
<tr>
<td>(N^1 \rightarrow R^1)</td>
<td>value series</td>
<td>bar chart, pie chart, etc.</td>
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<tr>
<td>(R^1 \rightarrow R^1)</td>
<td>function</td>
<td>(line) graph</td>
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<td>function over (R^2)</td>
<td>2D-height map in 3D, contour lines in 2D, false color map</td>
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<tr>
<td>(N^2 \rightarrow R^2)</td>
<td>2D-vector field</td>
<td>hedgehog plot, LIC, streamlets, etc.</td>
</tr>
<tr>
<td>(R^3 \rightarrow R^1)</td>
<td>3D-densities</td>
<td>iso-surfaces in 3D, volume rendering</td>
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<tr>
<td>((N^1 \rightarrow)R^n)</td>
<td>set of tuples</td>
<td>parallel coordinates, glyphs, icons, etc.</td>
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<td>$\mathbb{R}^1 \rightarrow \mathbb{R}^1$ function</td>
<td>(line) graph</td>
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PLplot Example 1 – Sinc Function

\[
\sin(x)/x
\]

PLplot Example 1 – Sine function

\[
\text{sine}
\]
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![Visualization Examples](image-url)
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- **Visualization Examples**
On Grids

On the organisation of sampled data
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?
Characteristics:

- Orthogonal, equidistant grid
- Uniform distances (in all dims., $dx=dy$)
- Implicit neighborhood-relationship (cf. array of arrays)
Regular Grid – Rectilinear Grid

- Regular Grid
  - $dx \neq dy$

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

- Characteristics:
  - non-orthogonal grid
  - grid-points explicitly given \((x[i,j])\)
  - Implicit neighborhood relationship
Characteristics:
- Grid-points and connections arbitrary
- Grid-points and neighborhood explicitly given
- Cells: tetrahedra, hexahedra
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 $7 \pm 2$
- Appr. 50–300 shades distinguishable (different for different colors)
- Rainbow color scale $\neq$ 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.)