Visualisierung 1
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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
◆ 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
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 – 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
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, ...
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)
3D → 2D projection

Abstract Visualization Object

Temperature

Pressure

0
Computational Sciences

Data Acquisition → Data Enhancement → Visualization Mapping → Rendering

Quantitative Analysis

Scientific Computing

Visual Computing

- 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

- Passive Visualization
- Interactive Visualization
- Interactive Steering

complexity, tech. demands

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
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)
How can data be represented?

- inherent spatial domain?
  - Yes ⇒ Recycle data space? Or not?
  - No ⇒ Select which representation space?
- Which dimension is used what for?
  - Relationship data space ⇔ data characteristics
  - Available display space (2D/3D)
  - Where is the focus?
  - Where can you abstract / save (e.g., too many dimensions)
<table>
<thead>
<tr>
<th>Data Space vs. Data characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1D</td>
</tr>
<tr>
<td>y=f(x)</td>
</tr>
<tr>
<td>2D</td>
</tr>
<tr>
<td>Spatial Curve x(t)</td>
</tr>
<tr>
<td>3D</td>
</tr>
<tr>
<td>CT-data d(x)</td>
</tr>
<tr>
<td>2D-Flow v(x)</td>
</tr>
</tbody>
</table>

Examples
## Visualization Examples

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

**Percentage of Sales**
- Randy
- Maurice
- Warner
- Steve

<table>
<thead>
<tr>
<th>Year</th>
<th>Widget Sales (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>5</td>
</tr>
<tr>
<td>1981</td>
<td>15</td>
</tr>
<tr>
<td>1982</td>
<td>12</td>
</tr>
<tr>
<td>1983</td>
<td>24</td>
</tr>
<tr>
<td>1984</td>
<td>28</td>
</tr>
<tr>
<td>1985</td>
<td>30</td>
</tr>
<tr>
<td>1986</td>
<td>20</td>
</tr>
<tr>
<td>1987</td>
<td>8</td>
</tr>
<tr>
<td>1988</td>
<td>12</td>
</tr>
<tr>
<td>1989</td>
<td>3</td>
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**Visualization Examples**

- **PLplot Example 1 - Sinc Function**
  - Function: $\sin(\pi x) / x$
  - Domain: $-2$ to $10$
  - Range: $0$ to $1.0$

- **PLplot Example 1 - Sine function**
  - Function: $\sin(x)$
  - Domain: $0$ to $360$
  - Range: $-1.2$ to $1.2$
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<td>3D-flow</td>
<td>streamlines, streamsurfaces</td>
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![Streamlines](image1.png) ![Streamsurfaces](image2.png)
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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**
  - $dx \neq dy$

- **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
Unstructured Grid

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

structured grids

orthogonal grids

equidist. grids

cartesian grids (dx=dy)

regular grids (dx≠dy)

rectilinear grids

curvi-linear grids

unstructured grids

hybrid grids

miscell.
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
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.)
Further Material