Information Visualization - Introduction

Eduard Gröller

Institute of Computer Graphics and Algorithms
Vienna University of Technology
Information Visualization

“The use of computer-supported, interactive, visual representations of abstract data to amplify cognition”
Outline

- Introduction
- Knowledge crystallization
- InfoVis reference model
  - Visual mappings, visual structures
  - View transformations
  - Interaction

Eduard Gröller
Vienna University of Technology
How Many Zeros in 100 Digits of PI?

<table>
<thead>
<tr>
<th>3.14159265358979</th>
<th>3.14159265358979</th>
</tr>
</thead>
<tbody>
<tr>
<td>265358979</td>
<td>265358979</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>3.23846264338327</td>
<td>3.23846264338327</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>950288419716939</td>
<td>950288419716939</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>937510582097494</td>
<td>937510582097494</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>459230781640628</td>
<td>459230781640628</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>620899862803482</td>
<td>620899862803482</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>534211706798214</td>
<td>534211706798214</td>
</tr>
</tbody>
</table>

Eduard Gröller
Vienna University of Technology

Courtesy of Jock Mackinlay
How Many Yellow Objects?

3.14159265358979
3.23846264338327
950288419716939
937510582097494
459230781640628
620899862803482
534211706798214

Eduard Gröller
Vienna University of Technology

Courtesy of Jock Mackinlay
Strategy: Use External World

\[
\begin{array}{c}
34 \\
\times 72 \\
68 \\
2380 \\
2448
\end{array}
\]

![Bar chart showing time to multiply mentally versus with paper and pencil.](chart.png)

Eduard Gröller
Vienna University of Technology

Courtesy of Jock Mackinlay
Nomograph

- visual devices for specialized computations
- easy to do “what if“-calculations

![Nomograph Diagram]

Rainfall Intensity (in/hr)

Maximum flow rate < 5000 cu. ft/s

Rainfall Duration (hr) – Tue Mar 02 04:56:40 CST 2004
Diagrams

Diagram of O-ring damage

Scattergraph of O-ring damage

Vienna University of Technology
Information Visualization (InfoVis)

External Cognition
use external world to accomplish cognition

Information Design
design external representations to amplify cognition

Visualization
computer-based, interactive

Scientific Visualization
typically physical data

Information Visualization
abstract, nonphysical data

Eduard Gröller
Vienna University of Technology
Knowledge Crystallization

Overview
Zoom
Filter
Details
Browse
Search query

Extract
Compose
Present

Task

Create, decide, or act

Develop insight

Instantiated visual structure

Search for visual structure

Forage for data

Reorder
Cluster
Class
Average
Promote
Detect pattern
Abstract

Eduard Gröller Vienna University of Technology

Courtesy of Jock Mackinlay
Dynamic HomeFinder

- Browsing housing market
- Data, schema (structure), task
Table Lens Tool

- Table visualization tool
- Instantiate schema
- Manipulate cases, variables

![Table Lens: Baseball Player Statistics](image)

Eduard Gröller
Vienna University of Technology
Knowledge Crystallization: Cost Structure

- Information visualization: Improve cost structure of information work
- Representation = data structure + operations + constraints
- Different cost relative to some task

Walking

Driving

Eduard Gröller

Vienna University of Technology
InfoVis Reference Model

- Raw Data: idiosyncratic formats
- Data Tables: relations (cases by variables) + metadata
- Visual Structures: spatial substrates + marks + graphical properties
- Views: graphical parameters (position, scaling, clipping, zooming,...)

Eduard Gröller
Vienna University of Technology
Data

Raw Data → Data Tables → Data Transformations
Raw Data

Documents → Words → Word Vectors

Other units:
- Sentence
- Paragraph
- Section
- Chapter
- Characters
- Pictures

Table:

<table>
<thead>
<tr>
<th>Document</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>...</td>
</tr>
<tr>
<td>Author</td>
<td>John</td>
<td>Sally</td>
<td>Lars</td>
<td>...</td>
</tr>
<tr>
<td>Date</td>
<td>16/8</td>
<td>11/4</td>
<td>24/7</td>
<td>...</td>
</tr>
</tbody>
</table>

Meaning

Eduard Gröller
Vienna University of Technology
Raw Data Issues

- Errors
- Variable formats
- Missing data
- Variable types
- Table Structure

```
<table>
<thead>
<tr>
<th>Document</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUWIEN</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UNIWIEN</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>about</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th>TUWIEN</th>
<th>D1,...</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIWIEN</td>
<td>D2,...</td>
</tr>
</tbody>
</table>
| about  | D1, D3, ...
| ...    | ...
```

```
<table>
<thead>
<tr>
<th>Document</th>
<th>D1</th>
<th>A</th>
<th>D3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>4</td>
<td>3.5</td>
<td>6</td>
</tr>
<tr>
<td>Author</td>
<td>John</td>
<td>Lars</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>16/8</td>
<td>Fall</td>
<td>24/7</td>
</tr>
</tbody>
</table>
| ...      | ... | ... | ...
```

Eduard Gröller
Vienna University of Technology

Courtesy of Jock Mackinlay
Data Transformations

- Process of converting Raw Data into Data Tables.
- Used to build and improve Data Tables.
Data Tables

- **Data Tables:**
  - Cases/Items
  - Variables
    - Nominal
    - Quantitative
    - Ordinal
  - Values
  - Metadata

<table>
<thead>
<tr>
<th>Name</th>
<th>N</th>
<th>Anna</th>
<th>Hans</th>
<th>Peter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Q</td>
<td>17</td>
<td>46</td>
<td>15</td>
</tr>
<tr>
<td>ID</td>
<td>O</td>
<td>11111</td>
<td>22222</td>
<td>33333</td>
</tr>
</tbody>
</table>
Data Transformations

- Values $\rightarrow$ Derived Values
- Structure $\rightarrow$ Derived Structure
- Values $\rightarrow$ Derived Structure
- Structure $\rightarrow$ Derived Values

<table>
<thead>
<tr>
<th>Derived value</th>
<th>Derived structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Sort</td>
</tr>
<tr>
<td></td>
<td>Class</td>
</tr>
<tr>
<td></td>
<td>Promote</td>
</tr>
<tr>
<td>Demote</td>
<td>X,Y,Z$\rightarrow$P</td>
</tr>
<tr>
<td></td>
<td>xzy</td>
</tr>
</tbody>
</table>
Visual Mappings

- Expressiveness
- Effectiveness

Eduard Gröller
Vienna University of Technology
Visual Mappings

- Spatial Substrate (Type of Axes)
  - Nominal
  - Ordinal
  - Quantitative

- Marks
  - Type: Point, Line, Area, Volume
  - Connection and Enclosure

- Axes Location
  - Composition
  - Recursion
  - Overloading
  - Folding
Axes Location

- Composition
- Overloading
- Folding
- Recursion

Eduard Gröller
Vienna University of Technology
Visual Structures

Classification by use of space:

- 1D, 2D, 3D
  - Refers to visualizations that encode information by positioning marks on orthogonal axes

- Multivariable >3D
  - Data Tables have so many variables that orthogonal Visual Structures are not sufficient
  - Multiple Axes, Complex Axes

- Trees
- Networks
1D Visual Structures

- Typically used for **documents** and **timelines**, particularly as part of a larger Visual Structure.
- Often embedded in the use of more axes, second or third axis, to accommodate large axes.
- Example:
  - **TileBars**

Eduard Gröller
2D Visual Structures

- Chart, geographic data
- Document collections
- Example:
  - Spotfire: 2D scattered graph

[Ahlberg, 1995]
3D Visual Structures

- Usually represent real world objects

- 3D Physical Data
  - E.g., VoxelMan

- 3D Abstract Data
  - E.g., Themescapes
Multivariable >3D

- Data Tables have so many variables that orthogonal Visual Structures are not sufficient.

- Example:
  - Parallel Coordinates
Parallel Coordinates

- Parallel 2D axes.
- Add/Remove data
  - Establish Patterns
  - Examine interactions.
- Useful for recognizing patterns between the axes
- Skilled user

Eduard Gröller Vienna University of Technology
Encode variables along a horizontal row
Vertical line specifies single variable
Blue line specifies a case

Eduard Gröller
Vienna University of Technology
Extended Parallel Coordinates

- Greyscale, color
- Histogram information on axes
- Smooth brushing
- Angular brushing

Eduard Gröller
Vienna University of Technology
Trees

- Visual Structures that refer to use of connection and enclosure to encode relationships among cases

- Desirable Features
  - **Planarity** (no crossing edges)
  - **Clarity** in reflecting the relationships among the nodes
  - Clean, non-convoluted design
  - Hierarchical relationships should be drawn directional

Eduard Gröller
Vienna University of Technology
Trees

H-Tree Layout

Cone Tree (3D)

Balloon View

Radial Layout

Eduard Gröller
Vienna University of Technology
Tree Maps [Johnson, Shneiderman, 1991]

Outline

Tree diagram

Venn diagram

Nested treemap

Treemap

Eduard Gröller
Vienna University of Technology
Networks

- Used to describe Communication Networks, Telephone Systems, Internet

- Nodes
  - Unstructured
  - Nominal
  - Ordinal
  - Quantity

- Links
  - Directed
  - Undirected

[Eduard Gröller Vienna University of Technology]

[Branigan et al, 2001]
Networks

Problems Visualizing Networks:

- **Positioning of Nodes**
- **Managing links so they convey the actual information**
- **Handling the scale of graphs with large numbers of nodes**
- **Interaction**
- **Navigation**

Eduard Gröller
Vienna University of Technology
Visual Form

Visual Structures → Views

View Transformations

Eduard Gröller

Vienna University of Technology
View Transformations

- Problems:
  - Scale
  - Region of Interest
  - How to specify focus?
    - Find new focus
    - Stay oriented
- Ability to interactively modify and augment visual structures, turning static presentations into visualizations

Eduard Gröller
Vienna University of Technology
Overview + Detail

- Provide both overview and detail displays
- Two ways to combine:
  - **Time** - Alternate between overview and detail sequentially
  - **Space** - Use different portions of the screen
Overview+Detail - Examples

- Detail only window
- Zoom & replace
- Single coordinated pair
- Tiled multilevel browser
Overview+Detail - Examples

- Free zoom and multiple overlap
- Bifocal magnified
- Fish-eye view (Focus+Context)
Focus + Context

- Overview Content
- Detail Content
- Dynamical Integration

Rationale

- Zooming hides the context
- Two separate displays split attention
- Human vision has both fovea and retina

Eduard Gröller
Vienna University of Technology
Focus + Context

- Filtering
  - Selection of cases
  - Manually or dynamically

- Selective aggregation
  - New cases

- Distortion
  - Relative changes in the number of pixels devoted to objects in the space
  - Types of distortion:
    - Size of the objects representing cases
    - Size due to perspective
    - Size of the space itself

Eduard Gröller  
Vienna University of Technology
Focus + Context - Examples

- Hyperbolic tree
- Perspective Wall
- Document Lens
Functions that distort visualizations by stretching or compressing them, giving the portion of visualization attended to more visual detail.

DOI - Degree Of Interest Function
Interaction

- Details-on-Demand
- Dynamic Queries
- Brushing

Eduard Gröller
Vienna University of Technology
Details-on-Demand

- Expands a set of small objects to reveal more of their variables

- Allows more variables to be mapped to the visualization

Looking for new office HQs???

Location: Favoriten Strasse 9
Rooms: 20
Conference Room: Yes
Availability: Occupied

Location: Michaelerstrasse 1
Rooms: 5
Conference Room: Yes
Availability: Under Construction

Eduard Gröller
Vienna University of Technology
Dynamic Queries

FilmFinder: Visual means of specifying conjunctions

Eduard Gröller
Vienna University of Technology
Brushing

- Used with multiple visualizations of the same objects
- Highlighting one case from the Data Table selects the same case in other views
- Linking and Brushing

[Doleisch et al.]
Further Readings

- The Information Visualization community platform http://www.infovis-wiki.net/index.php/Main_Page
- Ware, C., *Information Visualization - Perception for Design*, second edition 2004, Morgan Kaufmann
Interesting Links

- Google Public Data Explorer
  - http://www.google.com/publicdata/home

- Hans Rosling – Gapminder
  - http://www.ted.com/speakers/hans_rosling.html

- IBM – Many Eyes

- Visual Complexity
  - http://www.visualcomplexity.com /

- Further Links - External Links
  - http://www.cg.tuwien.ac.at/courses/InfoVis/index.html