Chapter 4 - Interaction with Visualizations

Dynamic linking, brushing and filtering in Information Visualization displays

Vorlesung „Informationsvisualisierung”
Prof. Dr. Florian Alt, WS 2013/14

Konzept und Folien (4th revised edition):
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Outline

• Definitions

• Direct Manipulation (DM)
  – Dynamic Queries
  – Movable Filters

• Common Interaction Techniques
  – Select
  – Explore
  – Reconfigure
  – Encode
  – Abstract / Elaborate
  – Filter
  – Connect
Direct Manipulation
Direct Manipulation (DM)

- Shneiderman 1982
- DM features
  - Visibility of all objects of interest
  - Incremental actions with rapid feedback on all actions
  - Reversibility of all actions, so that users are encouraged to explore without penalties
  - Syntactic correctness of all actions, so that every user action is a legal operation
- DM does not only make interaction easier for novice users but fundamentally extends visualization capabilities
Dynamic Queries

• Based on Direct Manipulation (DM)
• DM principles with regard to Dynamic Queries
  – Visual presentation of the query’s components
  – Visual presentation of results
  – Rapid, incremental, and reversible control of the query
  – Selection by pointing, not typing
  – Immediate, continuous feedback

• Implementation approach
  – Graphical query formulation: Users formulate queries by adjusting sliders, pressing buttons, bounding box selection…
  – Search results displayed are continuously updated (< 100 ms)
DQ in current search interfaces

• DQ have become widespread with fast search algorithms and increased computing capacity
  – search happens while typing in search terms in google search
  – new routes are calculated while point is dragged in google

![Google search interface with direct quotation and maps](image)
Summary Dynamic Queries

• Users can rapidly, safely playfully explore a data space – no false input possible
  – Users can rapidly generate new queries based on incidental learning
  – Visual representation of data supports data exploration
  – Analysis by continuously developing and testing hypotheses (detect clusters, outliers, trends in multivariate data)
  – Provides straightforward undo and reversing of actions

• Potential problems with DQ as implemented in the FilmFinder?
  – Limit of query complexity – filters are always conjunctive
  – Performance is limited for very large data sets and client / server applications
  – Controls require valuable display space
  – Information is pruned
  – Only single range queries and single selection in the alphaslider
Case Study: The Attribute Explorer

- Tweedie et al. 1994
- Example for DQ, brushing & linking and fuzzy search
- Linked histograms to search and explore multivariate data
- Filtering data via range sliders
- Color-coding to highlight and discriminate data cases across views
- Sensitivity information: visualizes how well data cases meet the filter requirements
- Particularly useful for zero-hits situations

Spence 2004
Dynamic Queries and Movable Filters

• Fishkin and Stone 1995
• Dynamic Queries (DQ)
  – Disjunctive queries can only be performed by sequential querying
  – Effect of DQ is global – no way to limit filtering to only a portion of the data
  – Number of possible queries is fixed in advance
• Combine approach with magic lens filters
  – Arbitrarily-shaped region with an operator that manipulates the view of underlying objects
  – Filters are spatially bounded – global context is maintained
  – Filters that overlap compose their effects in the overlap region

Stone et al. 1994
Idea & Implementation

• Each lens acts as a filter that screens on some attribute of the data

• Lens components
  – Filtering function (what to filter)
  – Composition mode (how to combine the filter result with lenses underneath, i.e. AND, OR, NOT)

• Composition modes are implemented as buttons on the lens

• Grouping: Replace a stack of lenses by a single compound lens, which also has a composition mode

• Compound lenses may contain other compound lenses

• Boolean queries and grouping allow queries of arbitrary complexity

• Multiple concurrent queries on different portions of the data space
Categories of Interaction
Categories of Interaction

- Select
- Explore
- Reconfigure
- Encode
- Abstract/Elaborate
- Filter
- Connect

This is only a small set of interaction techniques discussed in the paper: „Toward a Deeper Understanding of the Role of Interaction in Information Visualization“ by Ji Soo Yi, Youn ah Kang, John T. Stasko, and Julie A. Jacko, 2007.
Select: Mark something as interesting

- Select interaction techniques provide users with the ability to mark a data item(s) of interest to keep track of it.
- When too many data items are presented on a view, or when representations are changed, it is difficult for users to follow items of interest.
- By making items of interest visually distinctive, users can easily keep track of them even in a large data set and/or with changes in representations.

Example: Marking feature in Dust & Magnet

- Visualizes data items as specks of iron that move when magnets (attributes) are manipulated.
- With this technique, users can mark data items, and the marked items (KS1114, KS2085, and KS1103 in the figure) are labeled in red, so even after rearranging items, users can easily track and identify the location of items of interest.
Select: Mark something as interesting

• Another example: Placemark feature in Google Maps
• By putting a placemark on a location of interest, users can return to the location easily.
Select: Mark something as interesting

• Interestingly: The Select interaction techniques seem to work as a preceding action to subsequent operations.

• As shown in the Dust & Magnet example, users select data items of interest before rearranging, so that they can see where the items of interest would be located in a new arrangement.

• Rather than acting as a stand-alone technique, the Select interaction is coupled with other interaction techniques to enrich user exploration and discovery.
Explore: Show me something else

- The Explore interaction techniques enable users to examine a different subset of data cases.
- When users view data using an InfoVis system, they often can only see a limited number of data items at a time because of some combination of the large scale of the data set, view and/or screen limitations, and fundamental perceptual and cognitive limitations in human information processing.
- InfoVis system users typically examine a subset of the data to gain understanding and insight, and then they move on to view some other data.
- Explore interactions do not necessarily make complete changes in the data being viewed, however.
- More frequently, some new data items enter the view as others are removed.
Explore: Show me something else

• The most common Explore interaction technique is panning.
• Panning refers to the movement of a camera across a scene or scene movement while the camera stands still.
• Panning is often achieved by a special mode where the user grabs the scene and moves it with a mouse or by simply altering the view via scrollbars.
• Many InfoVis techniques use panning: Spotfire, Vizster, Dust & Magnet, SeeIT…
Explore: Show me something else

• Another example of Explore interaction: **Direct-Walk**
• Allows users to smoothly move the viewing focus from one position in information structure to another by “a series of mouse points or other direct manipulation methods.”
• Exploring one case may lead to another (e.g. hyperlinks on news page)
Explore: Show me something else

Example: Visual Thesaurus

– Visual Thesaurus is an online graphical dictionary
– A searched vocabulary is displayed at the center surrounded by related vocabularies.
– When one of the surrounding words is clicked, the word smoothly comes to the center and new related words surround this newly centered word.
Reconfigure: Show me a different arrangement

• The Reconfigure interaction techniques provide users with different perspectives onto the data set by changing the spatial arrangement of representations.

• One of the essential purposes of InfoVis is to reveal hidden characteristics of the data and the relationships between them.

• A good static representation often serves this purpose but a single representation rarely provides sufficient perspectives.

• Thus, many InfoVis tools incorporate Reconfigure interaction techniques that allow users to change the way data items are arranged or the alignment of data items in order to provide different perspectives on the data set.

• Sorting and rearranging columns operations in TableLens are good examples of Reconfigure techniques.
Reconfigure: Show me a different arrangement

Example: sorting of the „Horsepower“ column

– Users can now determine that horsepower values of cars are roughly correlated with cylinders, displacement, and weight.
– Users can also rearrange the columns to compare attributes of interest side by side.
Reconfigure: Show me a different arrangement

Example: Stacked histogram

- how are the banana sales progressing???
- http://www.hiraeth.com/alan/topics/vis/hist.html

- Baseline adjustment feature
- This enables users to better compare the heights of subsections of the histogram
- Without this technique, it is difficult to compare the values of subsections not initially on the bottom of the histogram.
Reconfigure: Show me a different arrangement

**Example: Selective Dynamic Manipulation**

– Similar feature in Selective Dynamic Manipulation system for comparing the height of bars in three-dimensional visualization.
Reconfigure: Show me a different arrangement

Example: Jitter operation

– Implemented in the Spotfire system
– When many data cases are drawn to particular vertical or horizontal rows, items may overlap resulting in occlusion.
– By applying jitter, the position of each item is randomly shifted by a small spatial increment, thus uncovering many more items and providing a better sense of the density of items in a region.
Reconfigure: Show me a different arrangement

Example: Jitter operation

- Similar operation in „Dust & Magnet“ known as the „Spread Dust“ operation that makes data items (dust particles) gradually repel each other so that occlusion decreases.
Encode: Show me a different representation

• The Encode techniques enable users to alter the fundamental visual representation of the data including visual appearance of each data element, including color, size, shape, etc.

• Very important in InfoVis: Visual elements serve an important role not only because they can affect pre-attentive cognition but also because they are directly related to how users understand relationships and distributions of data items.

• For instance, by encoding height information to a map using a spectrum of color users can better identify the height information (e.g. height of a mountain) without altering the spatial arrangement of a map.
Encode: Show me a different representation

- Simply changing how the data is represented (e.g. changing a pie chart to a bar chart) is an example of Encode.
- By changing a type of representation, users expect to uncover new aspects of relationship.
Encode: Show me a different representation

• Another widely used technique for Encode is the set of interaction techniques that alter the color encoding of a data set.

• Users can experiment with various color encoding schemes to find the most suitable one.
Encode: Show me a different representation

• Relevant color encoding schemes
  – Linear optimal
  – Heated object
  – Vegetation
  – Topographic
  – Blue to red
  – Ocean
  – Traffic light
  – …

• Color brewer for designing your own color schemes…
Encode: Show me a different representation

• Some systems also provide other encoding schemes:
  – Size
  – Orientation
  – Font
  – Shape
  – …

• Since some encoding techniques can be used simultaneously, they are often used together to encode many variables into representation (e.g. in Tag Clouds)

• Interactivity can be used to find the proper encoding scheme.
Abstract/Elaborate: Show me more/less detail

• Provide users with the ability to adjust the level of abstraction of a data representation
• Allow users to alter the representation from an overview down to details of individual data cases often many levels in-between
• The user‘s intent correspondingly varies between seeking more of a broad, contextual view of the data to examining the individual attributes of a data case or cases
Abstract/Elaborate: Show me more/less detail

Example: Details-on-Demand

- Animated details-on-demand techniques in SunBurst (i.e. angular detail, detail inside, and detail outside) provide such functionality by allowing particular subtrees in a hierarchy to be examined more closely without losing context of the entire structure.
Example: Tool-Tips

- Furthermore, simple tool-tip interaction techniques that provide detailed information when a mouse cursor hovers over a data item.
Abstract/Elaborate: Show me more/less detail

Example: Focus & Context

- The basic idea with focus–plus–context–visualizations is to enable viewers to see the object of primary interest presented in full detail while at the same time getting an overview–impression of all the surrounding information — or context — available.

- In a navigational system, one wishes to see both the whole map as well as smaller streets and surrounding environment of his current position

- difficult!

- One solution: Fisheye lens
Abstract/Elaborate: Show me more/less detail

Example: Overview and Detail

Overview and detail (from Civilization II game)
Abstract/Elaborate: Show me more/less detail

Example: Zooming

- **Geometric zooming** allows the user to specify the scale of magnification and increasing or decreasing the magnification of an image by that scale. This allows the user focus on a specific area and information outside of this area is generally discarded.

- **The fisheye zoom** is similar to the geometric zoom with the exception that the outside information is not lost from view; this information is merely distorted.

- **Semantic zooming** changes the shape or context in which the information is being presented. An example of this type of technique is the use of a digital clock within an application. In a normal view, the clock may show the hour of the day and date. If the user zooms in then the clock may alter its appearance by adding the seconds and minutes. If the user then zooms out, information is discarded with only the date remaining. The actual information did not change, only the presentation method. [Stephens, 2003]
Filter: Show me something conditionally

• Users can change the set of data items being presented based on some specific conditions.
• Users specify a range or condition, so that only data items meeting those criteria are shown.
• Data items outside of the range or not satisfying the condition are hidden from the display or they are shown differently.
• But the actual data usually remain unchanged so that whenever users reset the criteria, the hidden or differently shown data items can be recovered.
• The user is not changing perspective on the data, just specifying conditions on which data are shown.
Filter: Show me something conditionally

• Dynamic query controls as used in many InfoVis systems are a representative example of this type of interaction.

• Users select ranges by moving sliders or particular values by clicking on check boxes and the data cases meeting those constraints are immediately shown.

• Variants of dynamic query controls such as alpha sliders, range sliders, and toggle buttons are used to filter textual data, numerical data, and categorical data.
Filter: Show me something conditionally

Example: Name Voyager

– Website that illustrates the popularity of baby names over time, also supports a filtering interaction.

– Instead of using specific controls, users can filter the data items (e.g. names) through keyboard interaction.

– If a user types „K“ only the baby names starting with the letter „K“ are shown. If the user types „I“ following „K“ only those starting with „KI“ are shown, and so on…
Connect: Show me related items

• Interaction techniques that are used to
  – highlight associations and relationships between data items that are already represented
  – show hidden data items that are relevant to a specified item.

• When multiple views are used to show different representations of the same data set (e.g. 3D scatter plot and 2D scatter plot), it may be difficult to identify the corresponding item for a data case in other view(s).

• To alleviate this difficulty, the brushing and linking technique is used to highlight the representation of a selected data item in the other views being displayed.

• When a user selects a data item in the left view, the same data item of the right view is highlighted (circle in this case) simultaneously.
Connect: Show me related items

• Connect interactions can apply to situations involving a single view as well.

• For example, in Vizster, hovering a mouse cursor over a node highlights directly connected nodes (friends of friends).

• Here, the connection is not to other representations of the same item as in brushing but to items that have relationships to a focus element.
Other Interaction Techniques

• There are also other interaction techniques in InfoVis systems that do not fit in the categorization

• For example:

  – **Undo/redo**: These techniques allow users to go backward or forward to pre-existing system states (e.g. undo, redo, history, reset, …)

  – **Change configuration**: These techniques allow users to change various configurations and settings of a system

• Such techniques are common to many different types of applications not only to InfoVis! Hence, these are not included in this categorization scheme.
Chapter 5 - Graphs and Networks

Visualizing Relations

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Outline

• Introduction to graphs
  – Terminology
  – Challenges
  – Definitions
  – Data structures
  – Graph drawing

• Examples for Graph Visualization

• Metaphors for Graph Representation
  – Node-link Diagrams
  – Matrix Representations

• Case Study: Telephone Network Visualizations

• Graph Aesthetics

• Dynamic Graph Visualization
Introduction to Graphs
Graph Overview

- Graph: an abstract structure that is used to model information
- Can represent any information that can be modeled as objects and connections between those objects
- Objects represented by vertices
- Relations between objects represented by edges
- Commonly visualized as node-link diagrams
- Example domains
  - World Wide Web
  - Telephone networks
  - Financial transactions
  - Call graph in software engineering
  - CVS repositories
  - Social networks
  - Transportation networks
  - Co-citations…

- Graphs in InfoVis shall facilitate the understanding of complex patterns

Automatically generated airline database schema, Tamassia et al. 1988
Challenges in Graph Drawing

- **Graph Visualization (layout and positioning)**
  - How to present a graph to convey the most information and to make it easy to read and interpret it

- **Scale**
  - Performance of layout algorithms
  - Limited real estate of display area

- **Navigation and Interaction**
  - How to enable the user to move around the graph and inspect portions of the graph in detail
Definition

• A graph in this context refers to a collection of vertices or 'nodes' and a collection of edges that connect pairs of vertices. A graph may be undirected, meaning that there is no distinction between the two vertices associated with each edge, or its edges may be directed from one vertex to another.

• Graph:
  – A graph is an ordered pair $G = (V, E)$ consisting of
    • a set $V$ of vertices and
    • a set $E$ of edges that is a subset of $V \times V$
  – To avoid ambiguity, this type of graph may be described precisely as undirected and simple.
Definition

- Vertices belonging to an edge are called the endpoints, or end vertices of the edge.
- A vertex may exist in a graph and not belong to an edge.
- V and E are usually finite sets, and many of the well-known results are not true (or are rather different) for infinite graphs because many of the arguments fail in the infinite case.
- The order of a graph is $|V|$ (the number of vertices).
- A graph's size is $|E|$, the number of edges.
- The degree of a vertex is the number of edges that connect to it.
  - An edge that connects to the vertex at both ends (a loop) is counted twice.
  - In-degree and out-degree for directed graphs
Graphs Terminology

- Undirected graph
- Directed graph (usually indicated by arrows)
- Mixed graph – contains both directed and undirected graphs
- Planar graph: edges do not intersect

- Unweighted vs. weighted (nominal, ordinal quantitative) edges

- Adjacency
  - Two edges sharing a common vertex
  - Two vertices sharing a common edge
Graphs Terminology

- Path: a traversal of consecutive vertices along a sequence of edges
- Length of the path: number of edges that are traversed along the path
- Simple path: no repeated vertices within the path
- Cycle: a path in which the initial vertex of the path is also the terminal vertex of the path
- Acyclic: a simple directed graph not containing any cycles
Graphs Classes

- Planar graph
- Bipartite graph
- Complete graph
- Euler graph
  - Choice of route inside each land mass is irrelevant
  - Only important feature of a route is the sequence of bridges crossed
  - Allowed Euler to reformulate the problem in abstract terms, eliminating all features except the list of land masses and the bridges connecting them.
  - In modern terms, one replaces each land mass with an abstract "vertex", and each bridge with an abstract connection, an "edge", which only serves to record which pair of vertices (land masses) is connected by that bridge.
  - The resulting mathematical structure is called a graph.
Special Types of Graphs

• Network
  – Directed Graph
  – Usually weighted edges
  – No topological restrictions
  – Examples: social, economic, transportation networks

• Tree
  – No cycles
  – Usually directed edges
  – Usually special designated root vertex
  – Example: organizational chart
  – Will be topic of next lecture!
Data Structures for Graphs

• Storing and processing a graph on a computer
• Adjacency List - usually used for graphs with small numbers of edges
  – Row: edges leaving the vertex
  – Column: edges entering the vertex
• Adjacency Matrix - allows powerful matrix operations but is often more memory demanding
• Example for directed graph

<table>
<thead>
<tr>
<th></th>
<th>v1</th>
<th>v2</th>
<th>v3</th>
<th>v4</th>
</tr>
</thead>
<tbody>
<tr>
<td>v1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>v2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>v3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>v4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

v1 -> v2 -> v4
v2 -> v4
v3 -> v2 -> v4
v4 ->
Graph Drawing

• Many ways to draw a graph
• Vertices are usually represented by circles
• Edges are usually represented by open curves between vertices
• Node-link diagram
• Potential encoding attributes
  – Color
  – Size
  – Form / Shape
• Labeling is often difficult due to clutter
Graph Drawing

- Layout algorithms can be categorized by the type of layout they generate
- Planar: edges do not intersect
- Straight, polyline (edge with bends) or curved lines
- Orthogonal: polyline drawing that maps each edge into a chain of horizontal and vertical segments

Images taken from Cruz & Tamassia
Graph Drawing

• Grid-based: vertices (and bends of the edges) have integer coordinates – implies minimum distance between vertices and nonincident edges

• Upward / downward drawing for directed acyclic graphs: make edges flow in the same direction, e.g. for visualizing hierarchies

Images taken from Cruz & Tamassia
Empirical Results

• Purchase 1997
  – Compare task performance on five pairs of graphs
  – Graph pairs differed according to numbers of edge bends, edge crosses, maximizing the minimum angle, orthogonality and symmetry
  – Result: Reducing crossings is by far most important

• Ware et al. 2002
  – Experimental task: finding the shortest path in spring layout graphs
  – Results indicate the following prioritization of metrics
    • Geometric length of the path (implicit property of a graph)
    • Continuity (keeping multi-edge paths as straight as possible)
    • Number of edge-crossings
Examples for Graph Visualization
Various Examples of Graph Drawings

Enron

- Exploring Enron: http://jheer.org/enron/
Social Network

• They rule: http://www.theyrule.net/2004/tr2.php
Social Network?

- Co-occurrences of names in the new testament: http://www-958.ibm.com/software/data/cognos/manyeyes/visualizations/89ade5ae1055f49801105a9fb0ac03fd
Copurchase Network

- **Touch graph:** [http://www.touchgraph.com/TGAmazonBrowser.html](http://www.touchgraph.com/TGAmazonBrowser.html)
Music + Movie Network

• Liveplasma: http://www.liveplasma.com/
• Mapping and data source unclear
Transportation Network

http://de.wikipedia.org/wiki/U-Bahn_M%C3%BCnchen
Transportation Network

- Objectives
  - Facilitate understanding of network connections
  - Fit size and aspect ratio constraint (positioned above the doors in the underground)

- Heavily distorted geographic positions, but still good readability for identifying shortest paths between stations

http://de.wikipedia.org/wiki/U-Bahn_M%C3%BCnchen