Semi-Automatic Information and Knowledge Systems
:
Hierarchical Data Visualization & Ontology Visualization

Monika Lanzenberger

- Information Visualization
- Hierarchical Data Visualization Techniques
- Ontology Visualization
- Alignment Visualization

InfoVis is ...

... the process of transforming data, information, and knowledge into visual form making use of humans' natural visual capabilities.

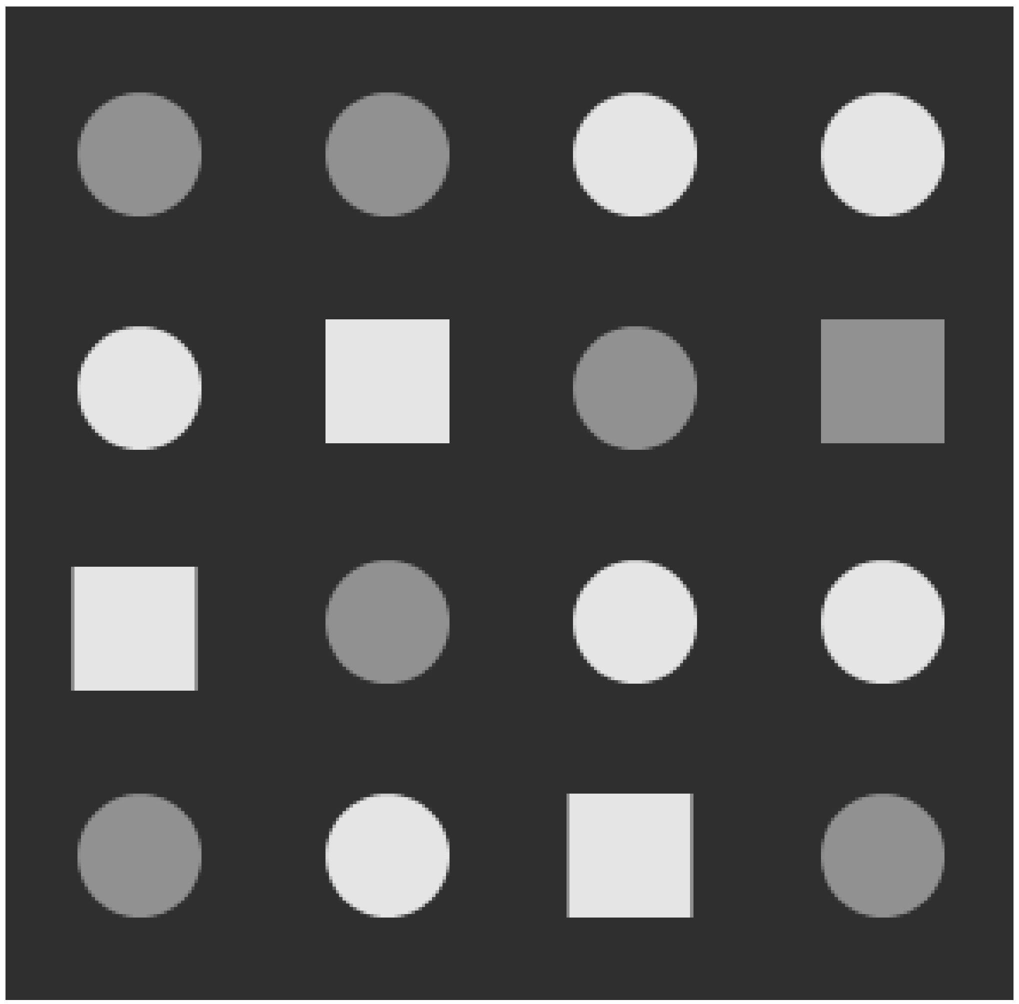
... the computer-assisted use of visual processing to gain understanding.

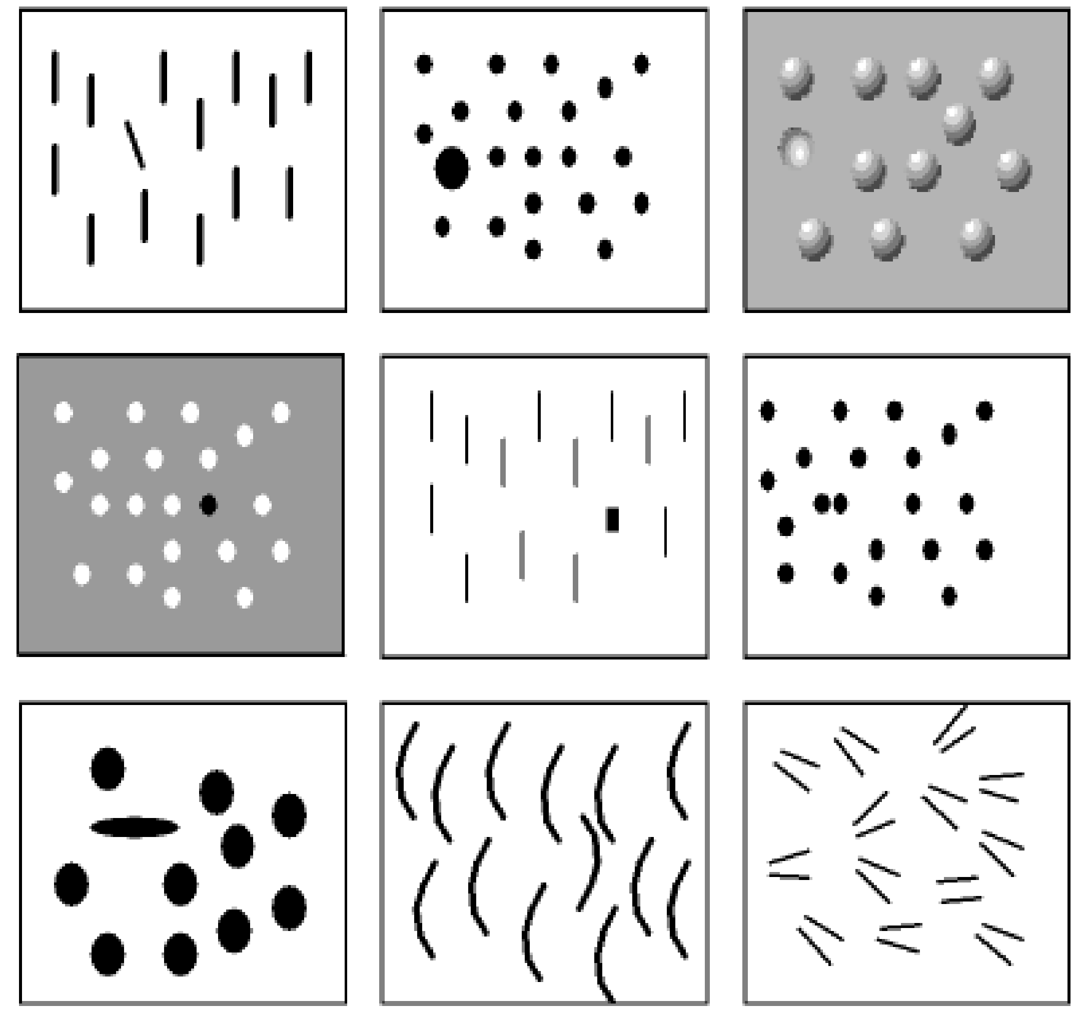
... providing the user with an overview first and then details on demand (<-> text).

... based on pre-attentive features (< 200ms).

[Card & Mackinlay,1997, Gershon, Eick, Card,1998, Ware, 2000]

Information Visualization is ...





... based on pre-attentive features (< 200ms).

[Card & Mackinlay,1997, Gershon, Eick, Card,1998, Ware, 2000]

- Visualization of abstract data
  (e.g., financial transactions, insurance risks, etc.)
  means to find spatial representations (2D, 3D).

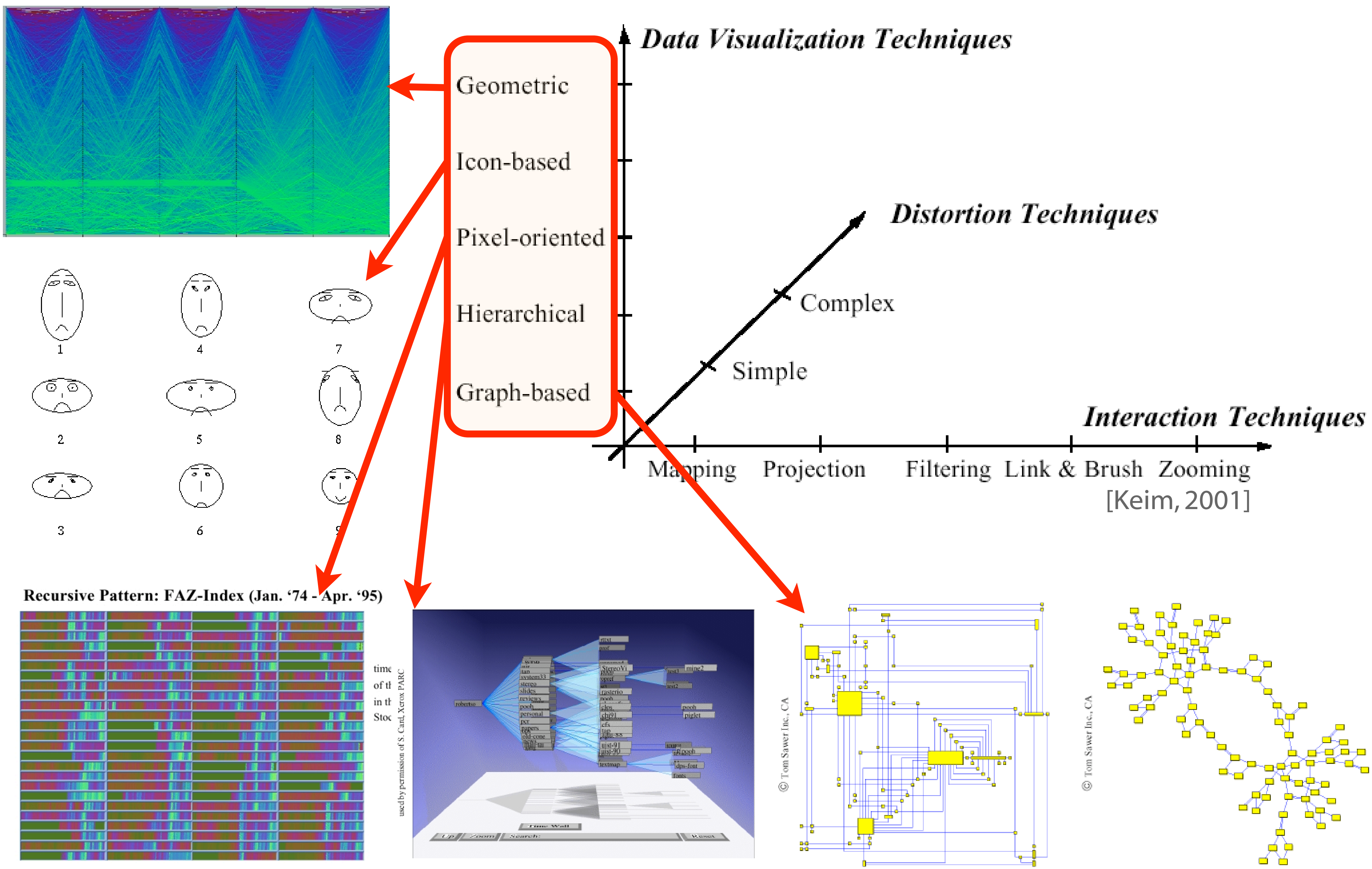
- No inherent spatial structure available,
  so the designer / user needs to decide
  which dimensions are represented by space: Mapping.

- Entities (e.g., people, terms) and relations (e.g., part-of, is-a)
- Both can have sets of attributes (duration, color, time, etc.)

- Types of attributes
  1. nominal, ordinal, interval, ratio
  2. Category data (nominal),
     integer data (ordinal),
     real-number data (interval & ratio)

- High-frequency versus high-structural

[Ware: Information Visualization, 2000]


Data Visualization Techniques
Geometric
Icon-based
Pixel-oriented
Hierarchical
Graph-based
Distortion Techniques
Complex
Simple
Interaction Techniques
Mapping
Projection
Filtering
Link & Brush
Zooming
[Keim, 2001]
Recursive Pattern: FAZ-Index (Jan. '74 - Apr. '95)

Coupling views by:

- **Slaving**
  movements in one view are automatically propagated in the other views

- **Linking**
  connects the data items of one view with the data items of the other views e.g., done by **brushing**: user selects and highlights items in one view and the corresponding items are highlighted automatically

[Baldonado, 2000]

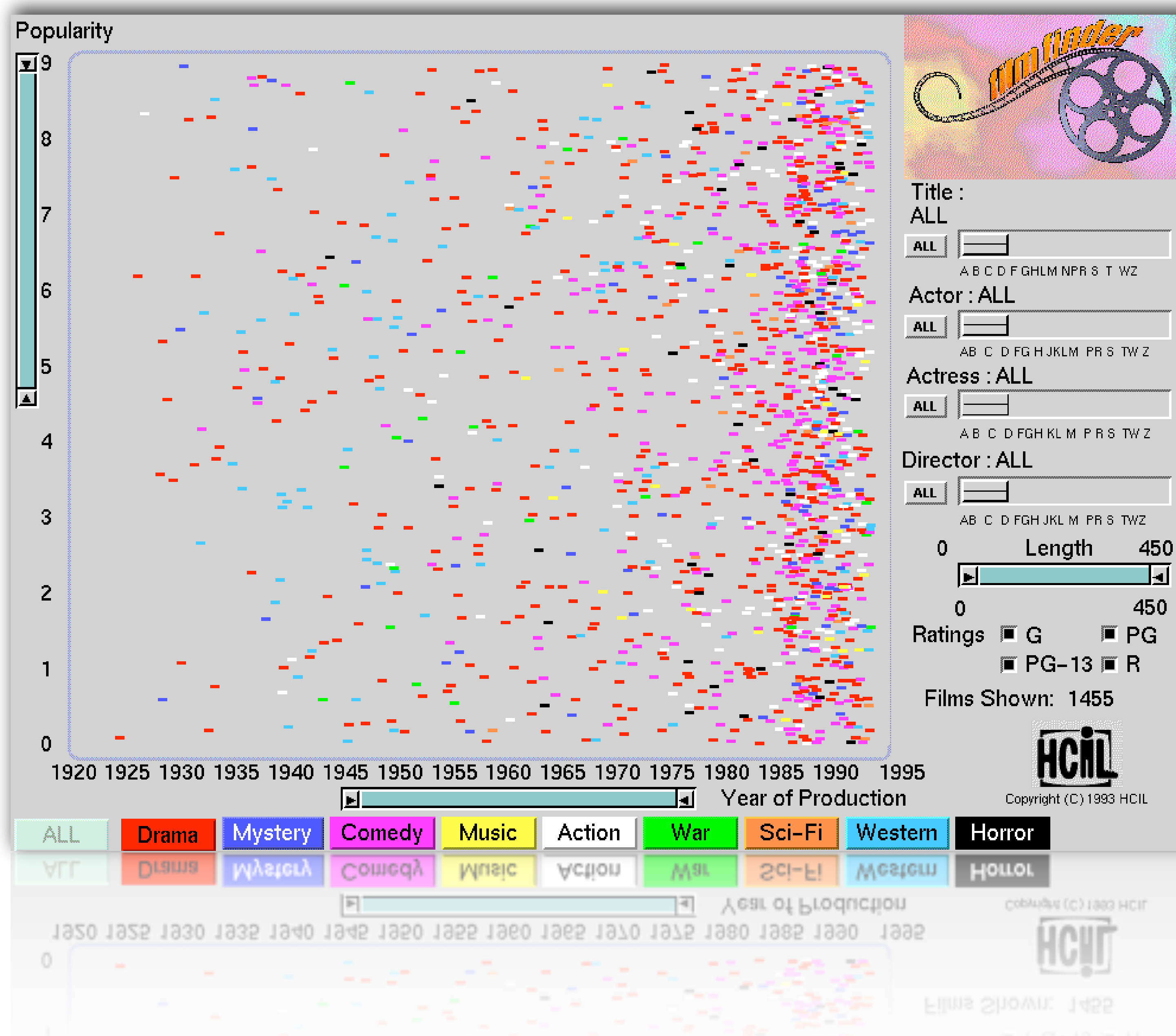
Different ways in encoding information visually:

- Space
  (See details next slide)
- Marks (in space)
  Points, lines, areas, volumes
- Connections & enclosures
- Retinal properties
  Crispness, shape, resolution, transparency, color, grayscale
- Temporal changes
- Viewpoint transformations

[Card, Mackinlay & Shneiderman, 1999]

- **Composition**

  The orthogonal placement of axes, creating a 2D metric space



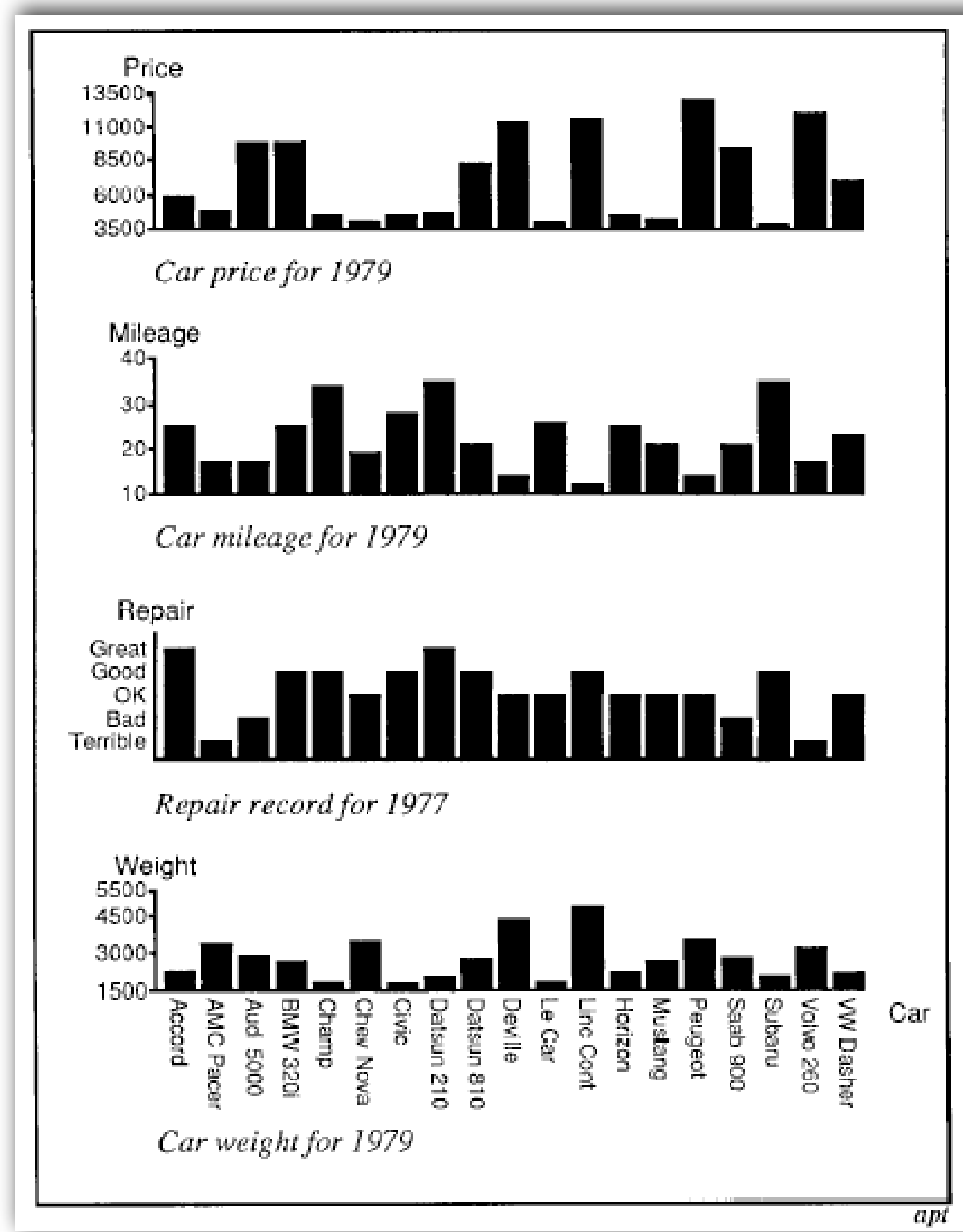
[Card, Mackinlay & Shneiderman, 1999]

- Composition

  The orthogonal placement of axes, creating a 2D metric space

- Alignment

  The repetition of an axis at a different position in the space



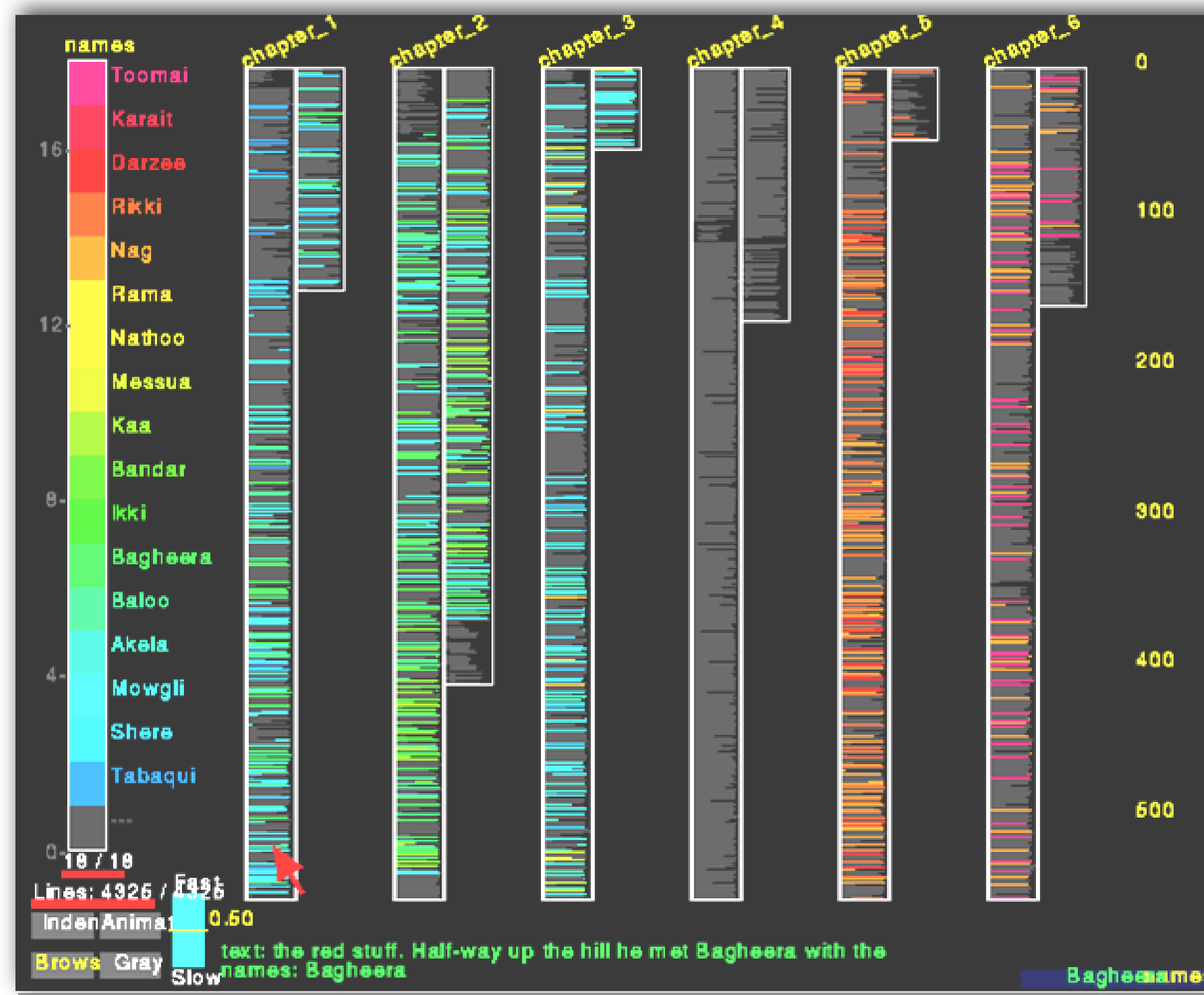
[Card, Mackinlay & Shneiderman, 1999]

- Composition

  The orthogonal placement of axes, creating a 2D metric space
- Alignment

  The repetition of an axis at a different position in the space
- **Folding**

  The continuation of an axis in an orthogonal direction



[Card, Mackinlay & Shneiderman, 1999]

- Composition

  The orthogonal placement of axes, creating a 2D metric space

- Alignment

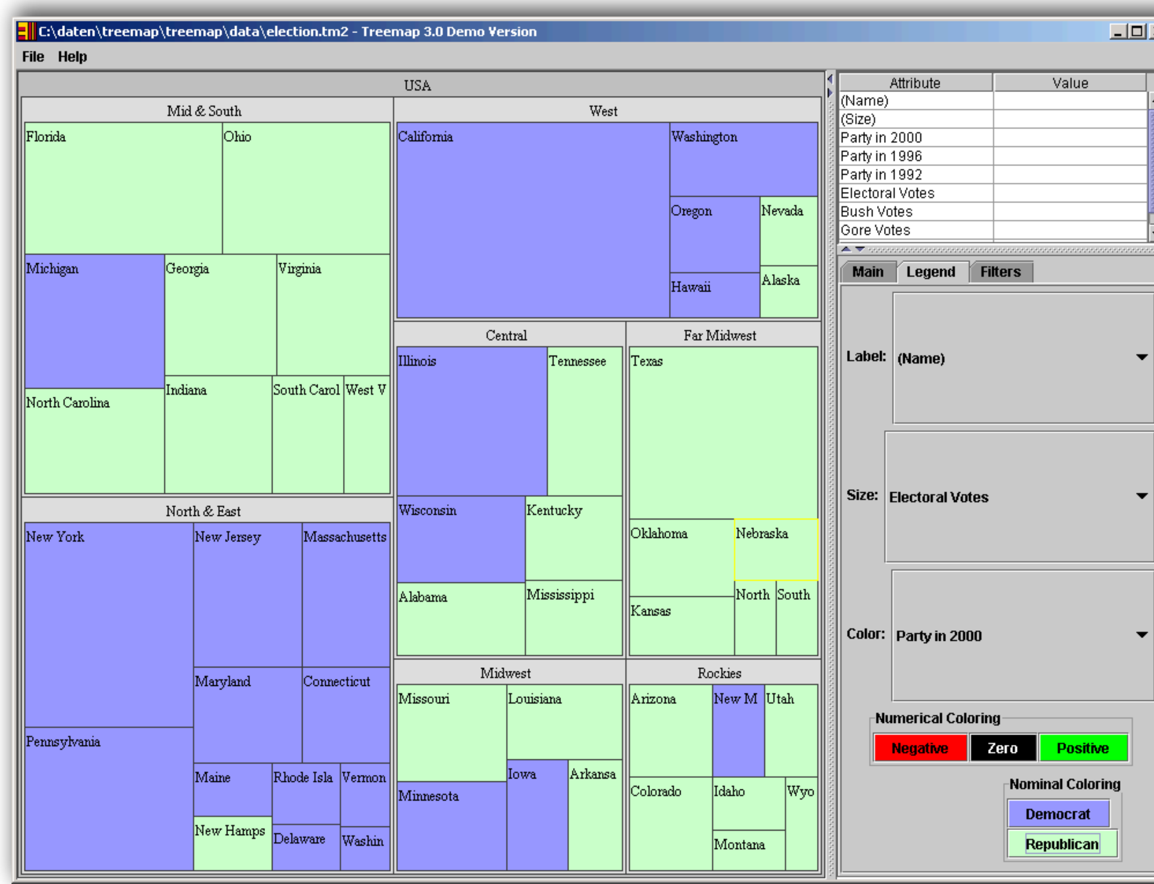
  The repetition of an axis at a different position in the space

- Folding

  The continuation of an axis in an orthogonal direction

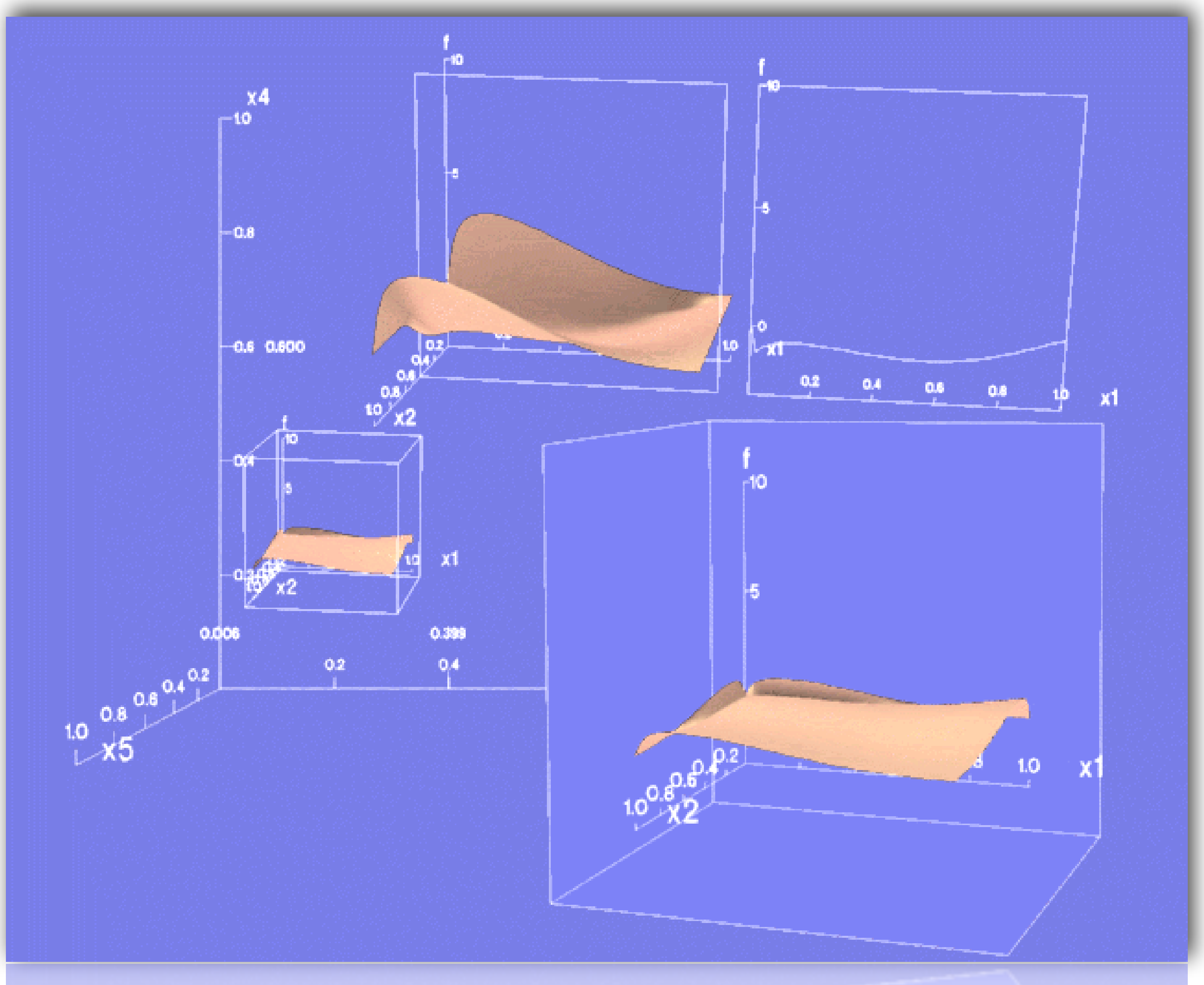
- **Recursion**

  The repeated subdivision of space



[Card, Mackinlay & Shneiderman, 1999]

- Composition
  The orthogonal placement of axes, creating a 2D metric space
- Alignment
  The repetition of an axis at a different position in the space
- Folding
  The continuation of an axis in an orthogonal direction
- Recursion
  The repeated subdivision of space
- **Overloading**
  The reuse of the same space



[Card, Mackinlay & Shneiderman, 1999]

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Basic Idea: Visualization of data using a hierarchical partitioning into subspaces

Examples are:

- Dimensional Stacking [LeBlance et al. 1990]
- Worlds-within-Worlds [Feiner & Besherss 1990]
- Treemaps [Shneiderman 1992; Johnson, 1993]
- Sequoiaview [van Wijk, et al. 1999; 2002]
- Cone/Cam Trees [Robertson, Mackinlay, Card 1991]
- Cheops [Beaudoin et al., 1996]
- InfoCube [Rekimoto & Green 1993]

Screen-Filling Methods

- Hierarchical partitioning of the screen depending on the attribute values
- Overcoming space limitations

Alternative Partitioning

- x- and y-dim of the screen

Attributes - User-Defined

- for partitioning and their ordering

Color Correspond to Add. Attributes

Overview over

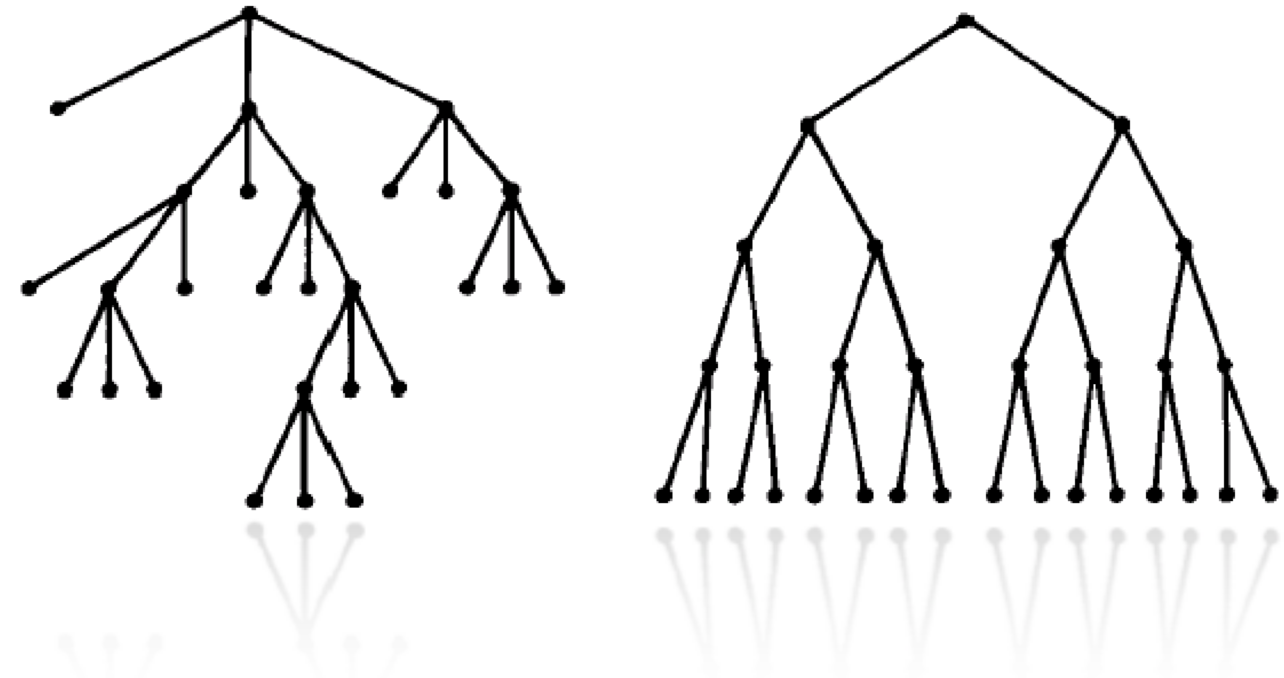
- Large amount of hierarchical data (e.g., file system)
- Data with multiple ordinal/quant. attributes (e.g., census data)

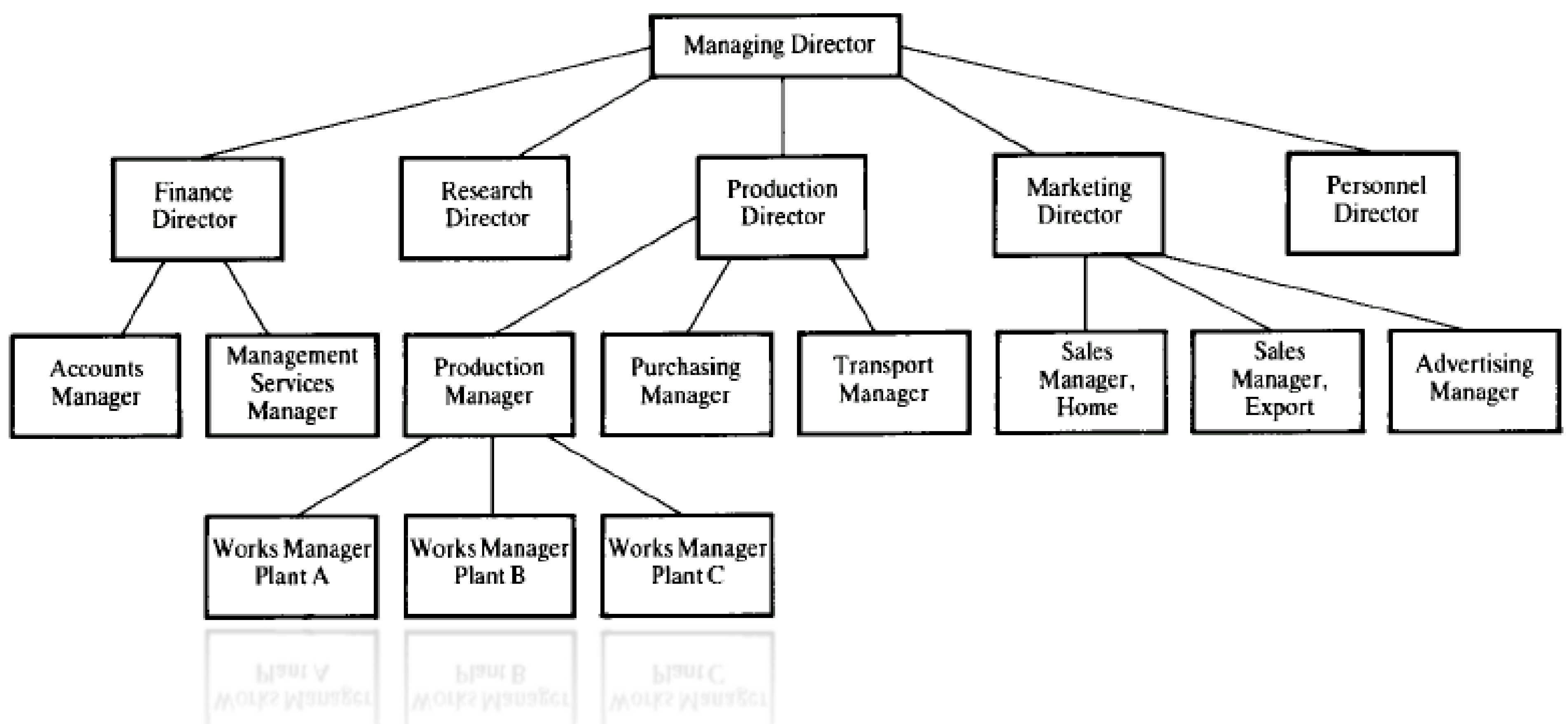
[Shneiderman 1992; Johnson, 1993]

Hierarchical Data

Trees:

- Ordered
- Acyclical
- Hierarchical





[Shneiderman 1992; Johnson, 1993]

Horizontal

- Corresponding to Text

Vertical

- Traditional

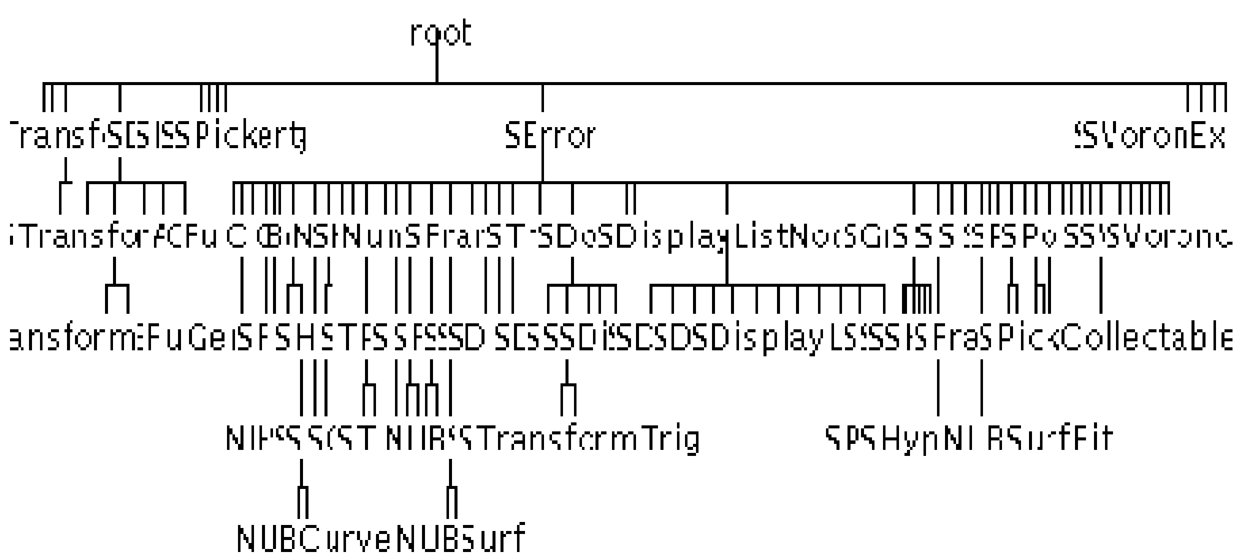


Figure 5: A Standard 2D Tree.

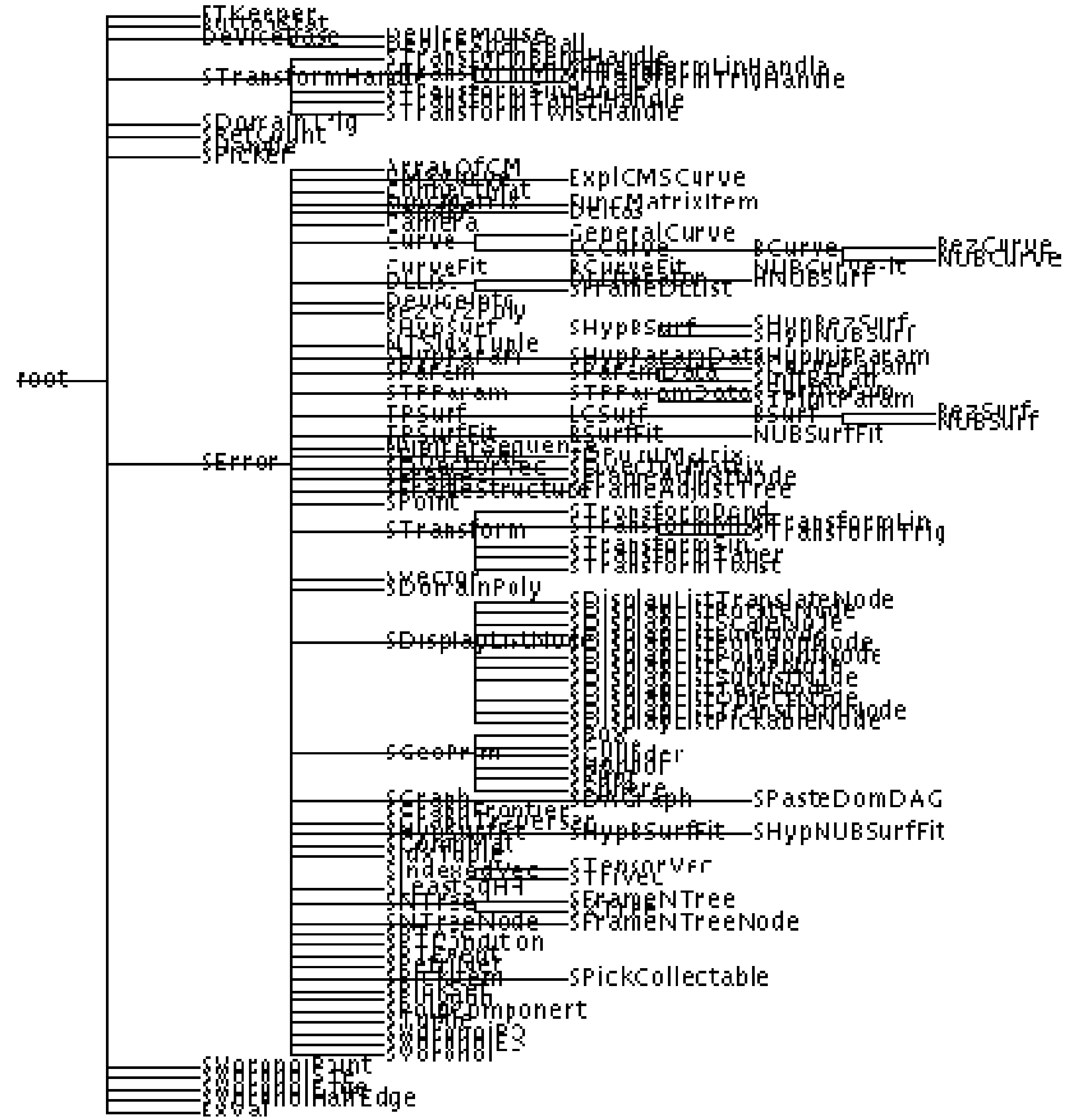
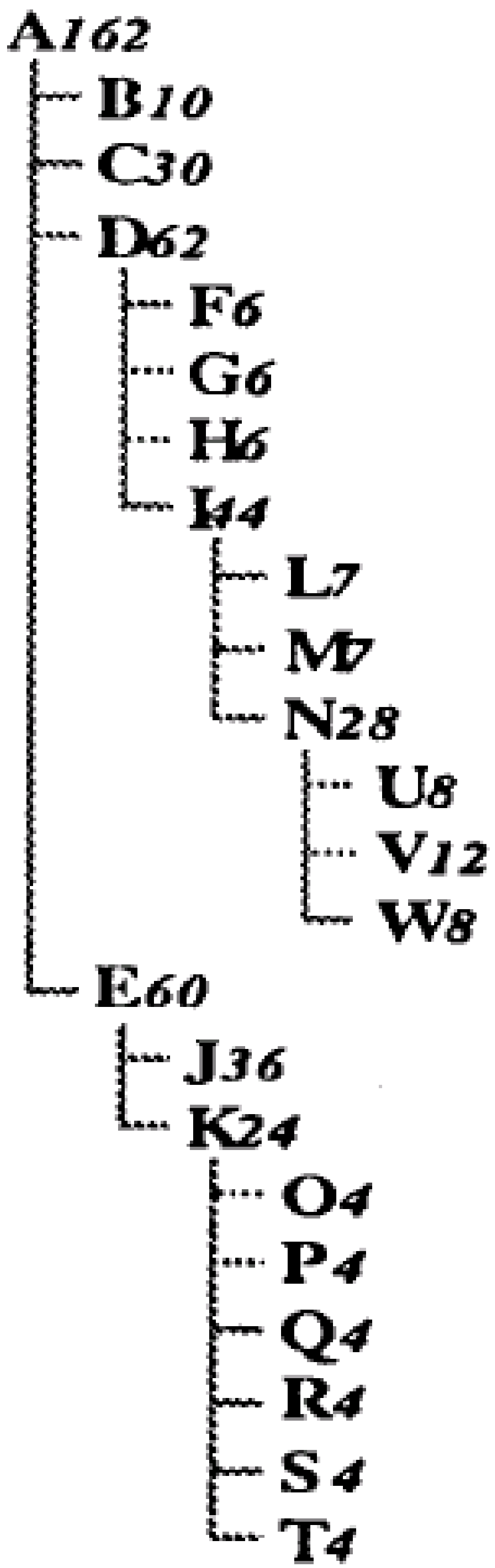
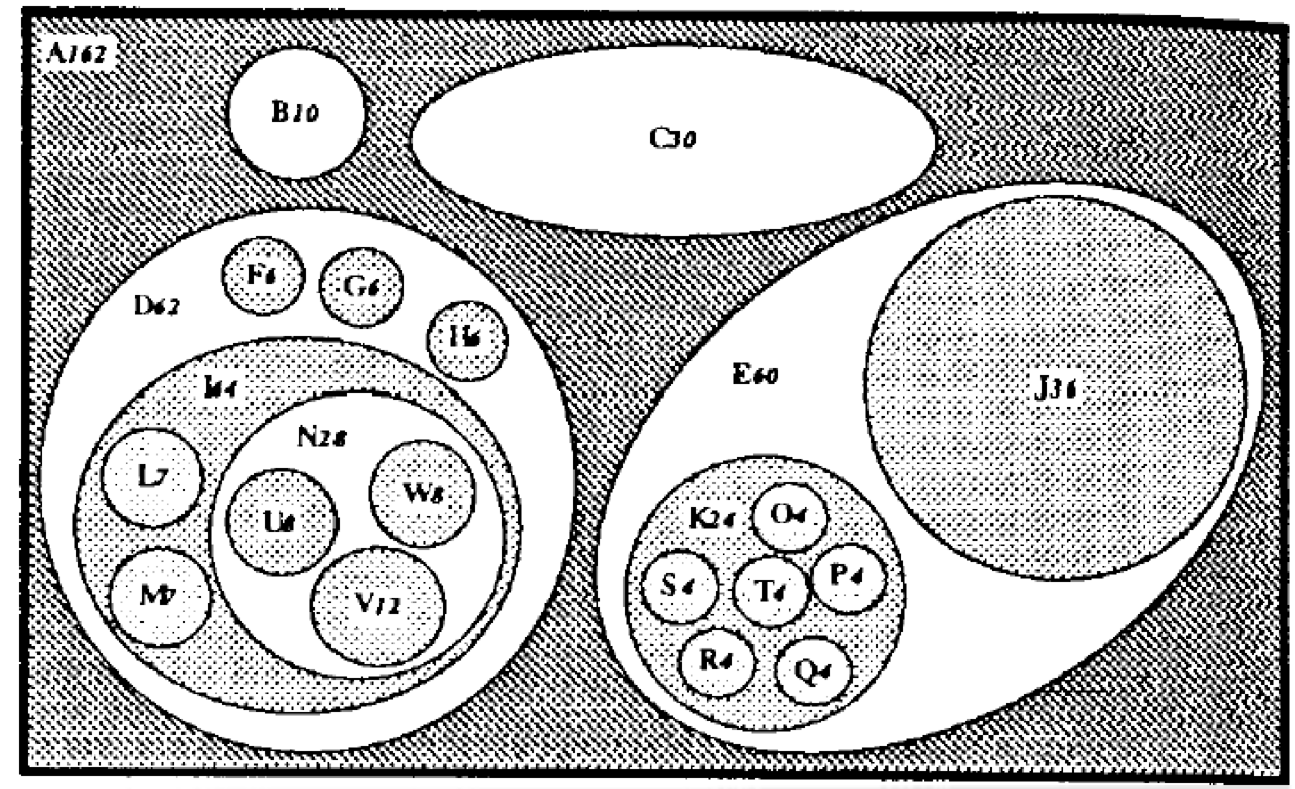
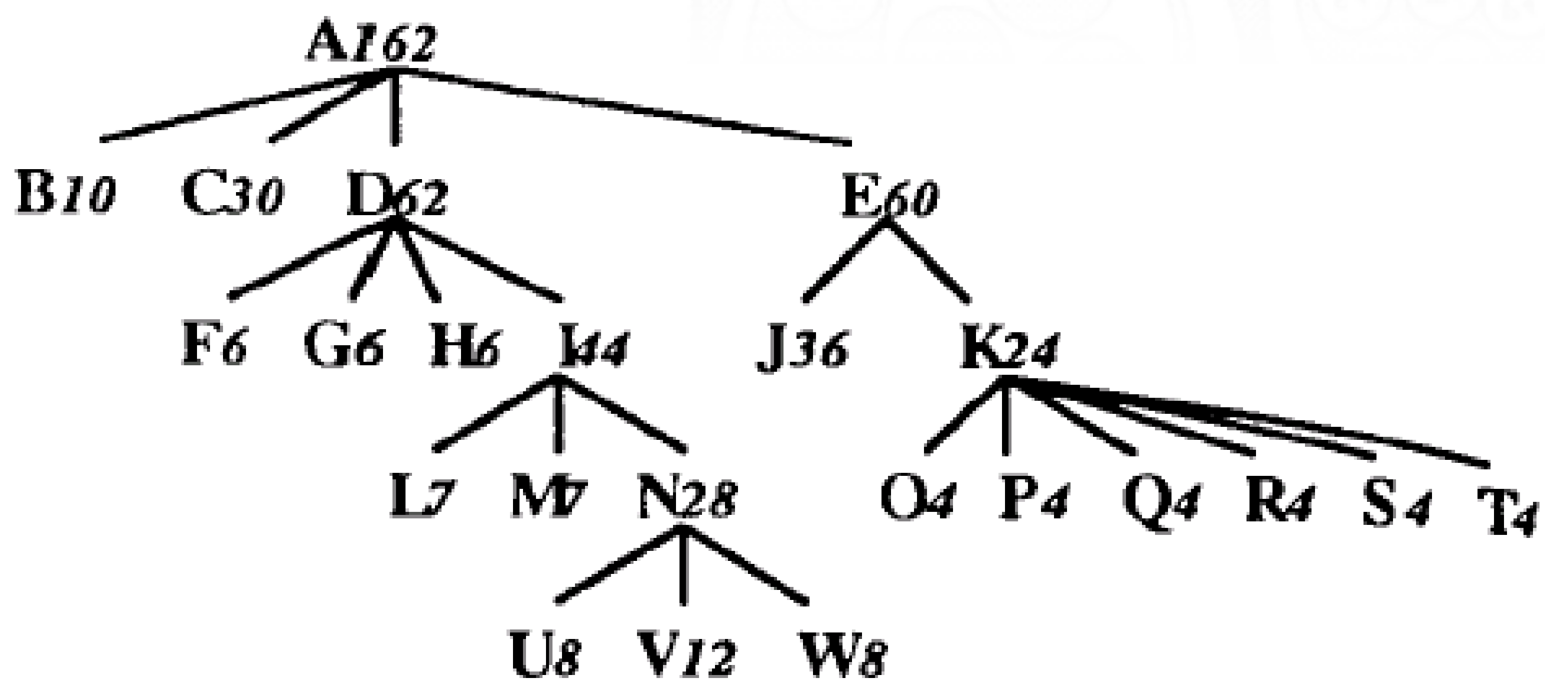


Figure 6: A Rotated 2D Tree.

[Shneiderman 1992; Johnson, 1993]

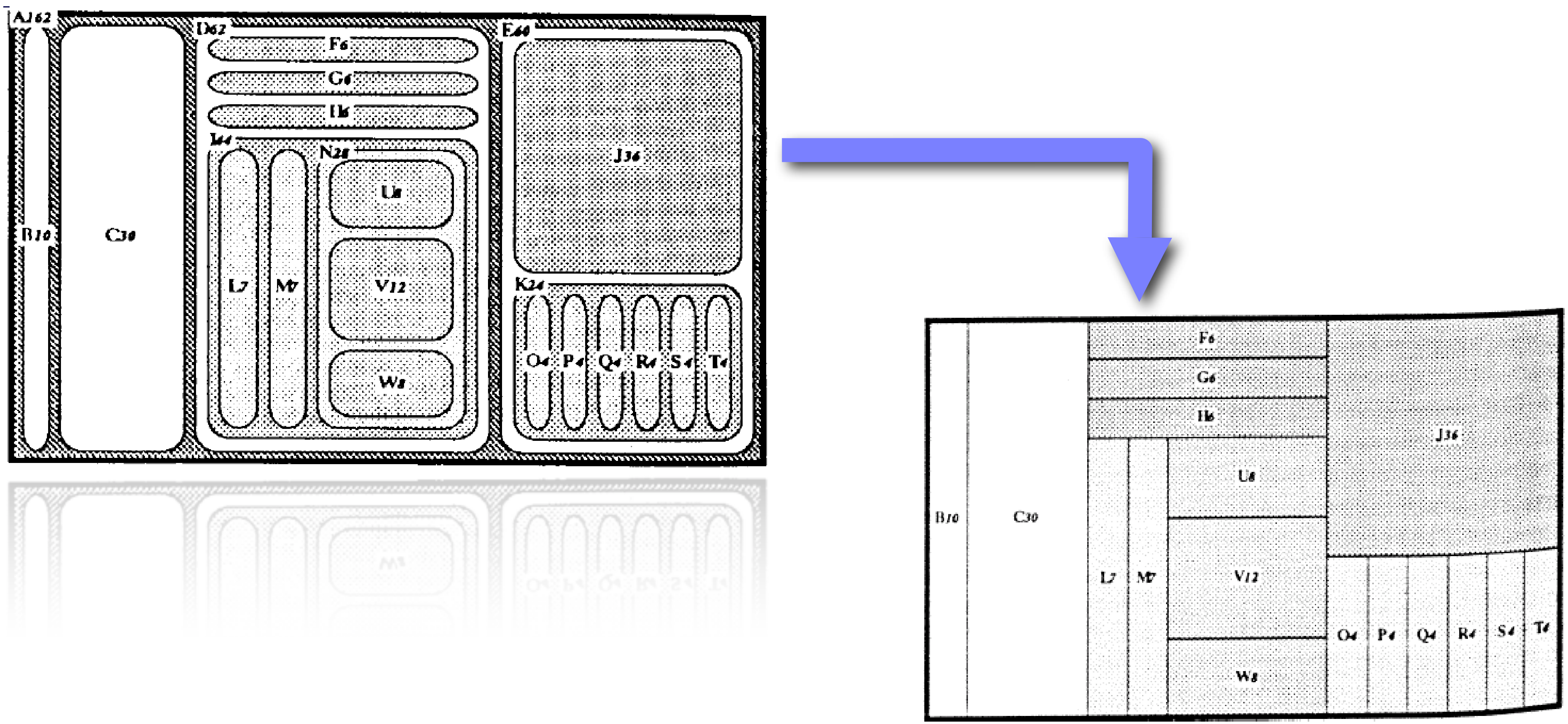






[Shneiderman 1992; Johnson, 1993]

Nested Treemap

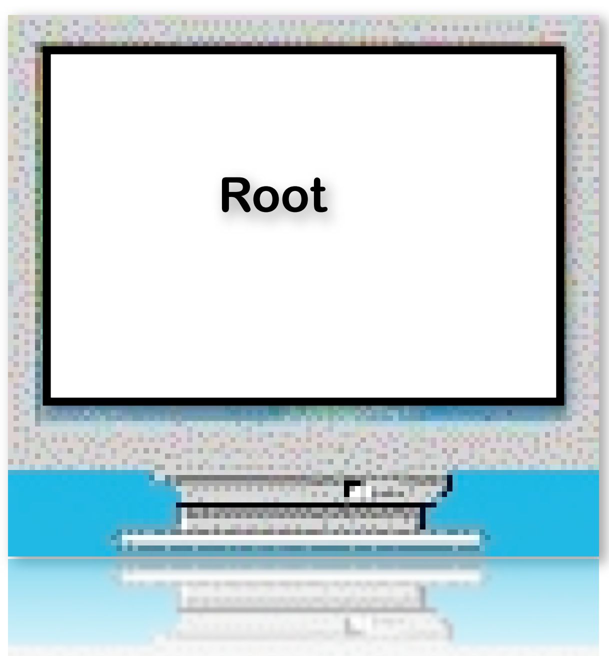


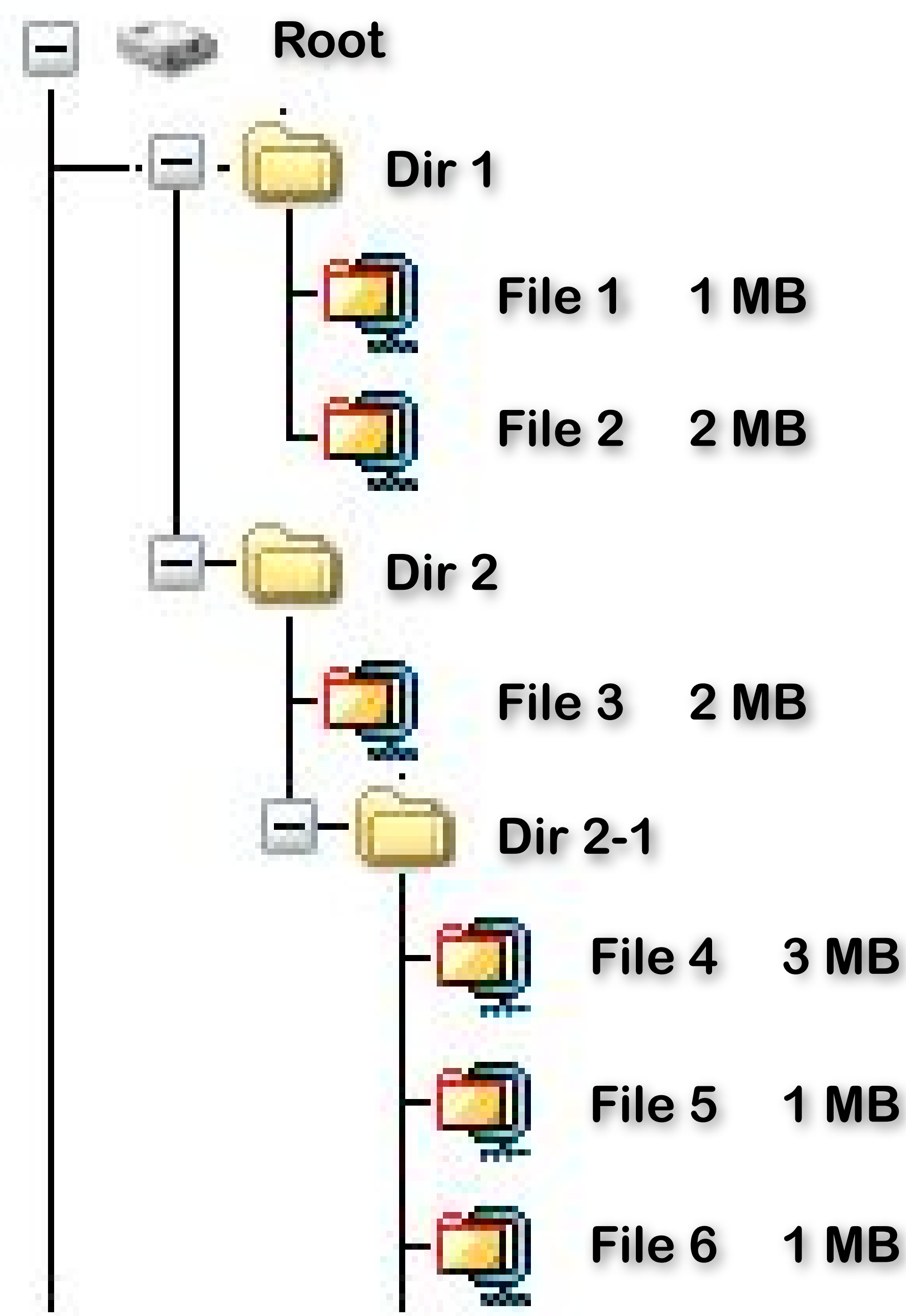
[Shneiderman 1992; Johnson, 1993]

File System:

- 3 Folders
- 6 Files

Root --> whole Screen



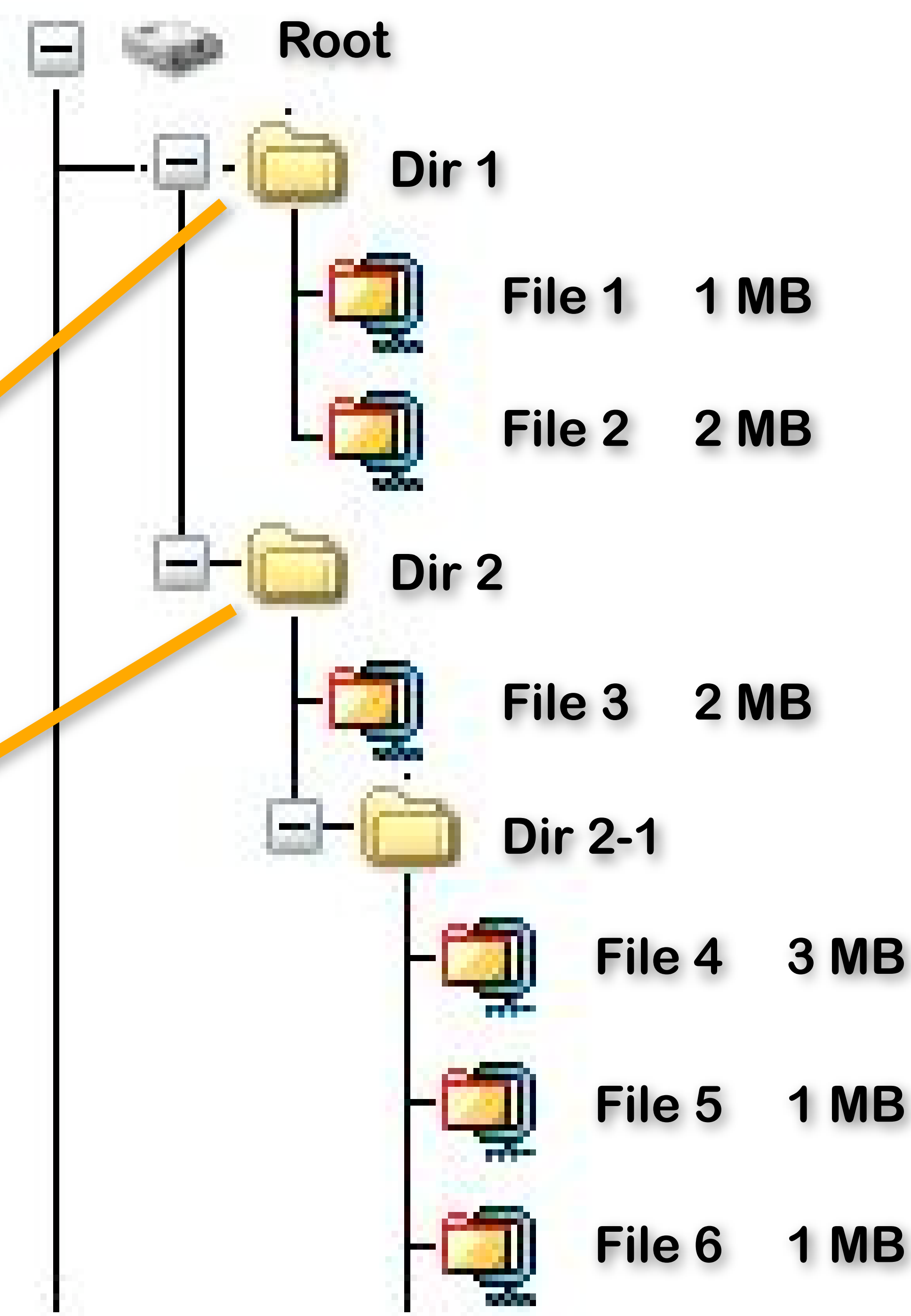


[Shneiderman 1992; Johnson, 1993]

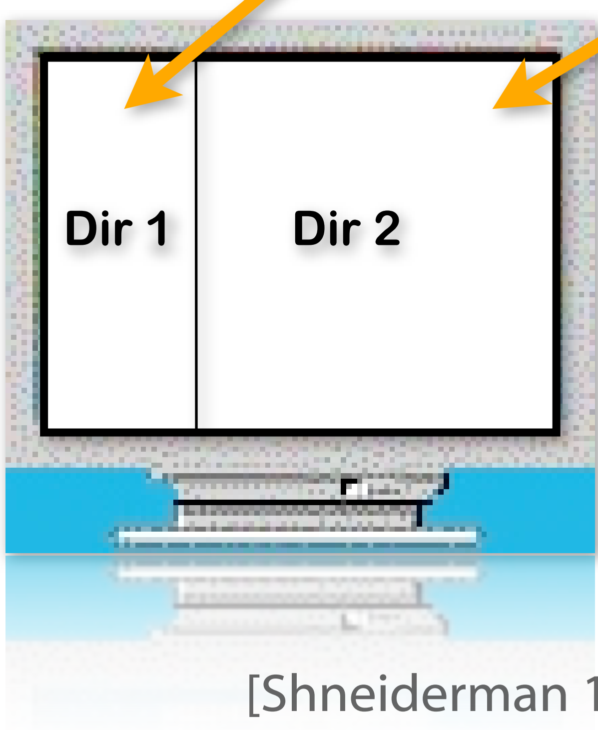
Example: File Structure to Tree

File System:

- 3 Folders
- 6 Files



Cutting - according to the size (30% and 70% of the space)

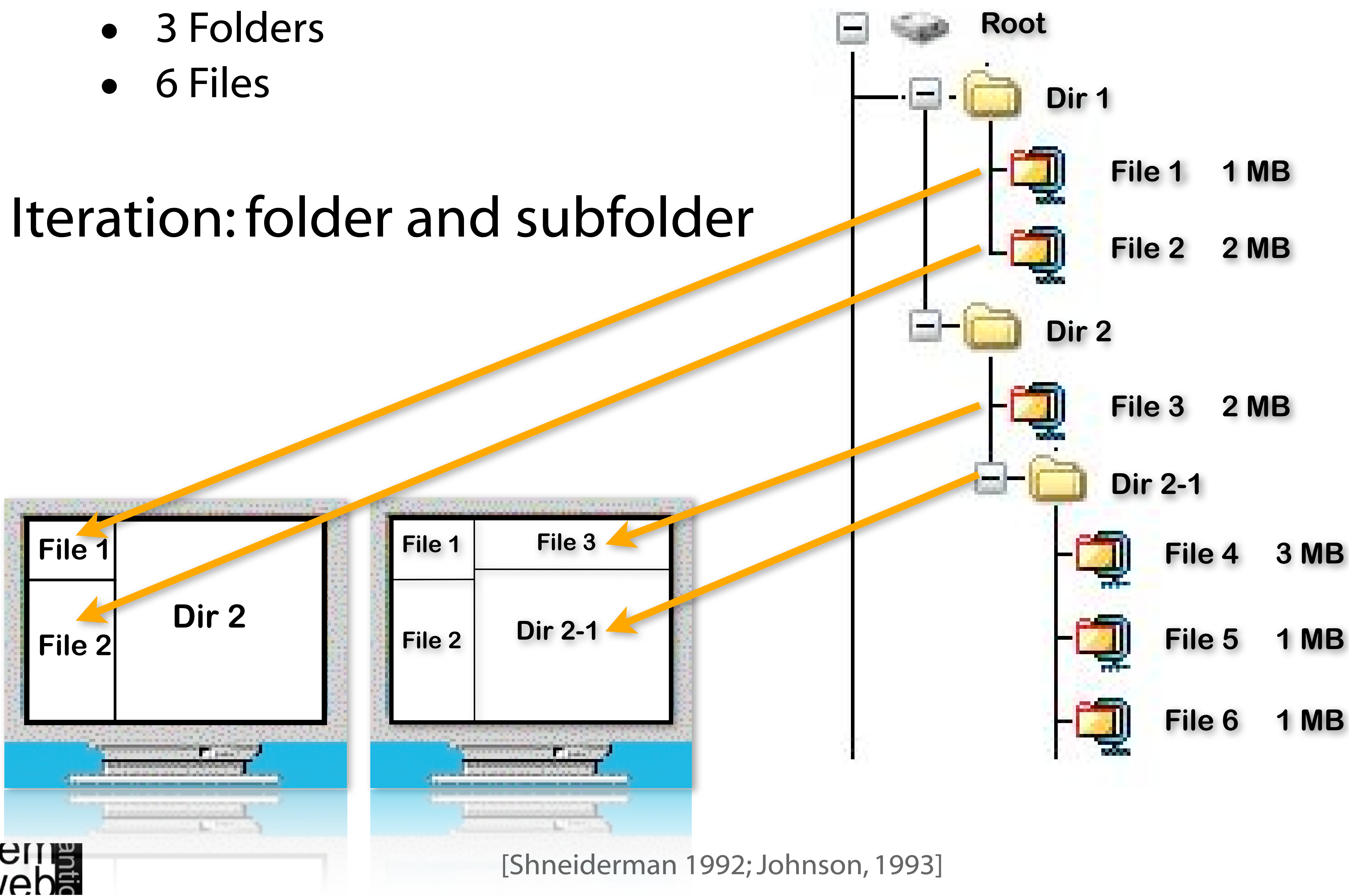


[Shneiderman 1992; Johnson, 1993]

File System:

- 3 Folders
- 6 Files

Iteration: folder and subfolder

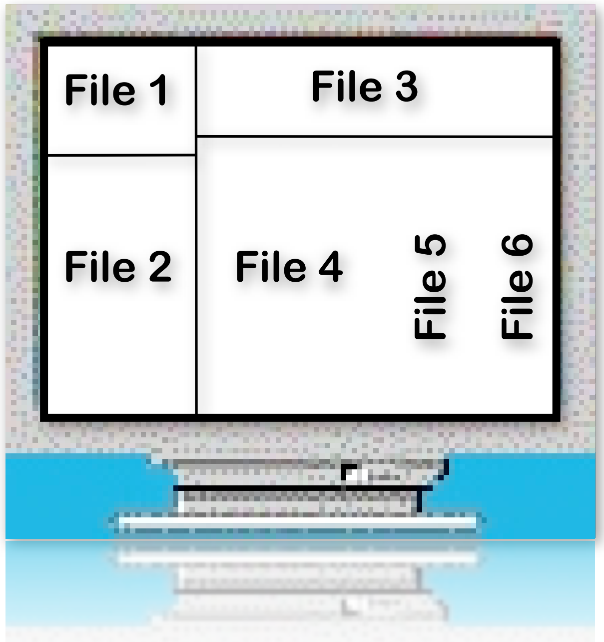


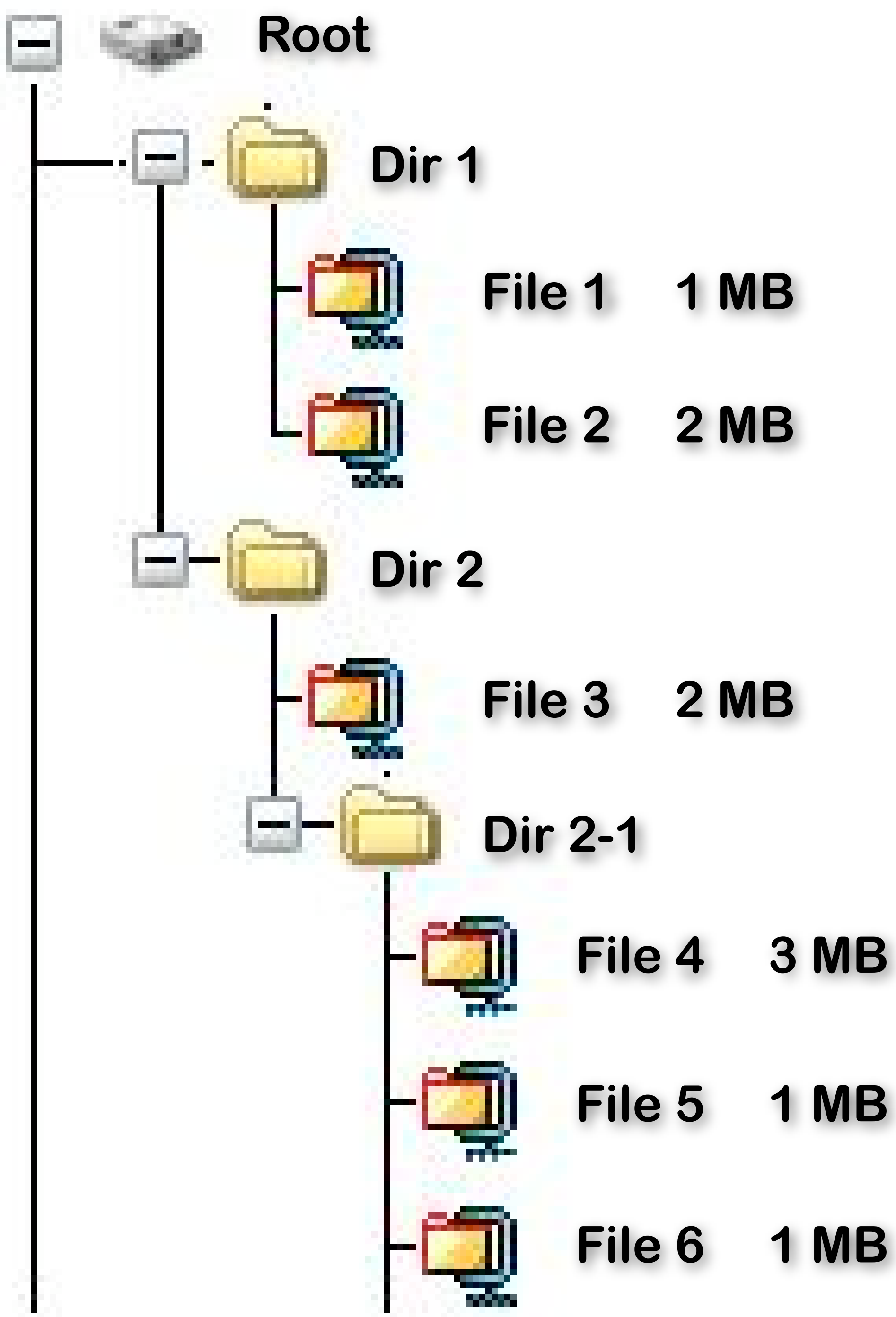
[Shneiderman 1992; Johnson, 1993]

File System:

- 3 Folders
- 6 Files

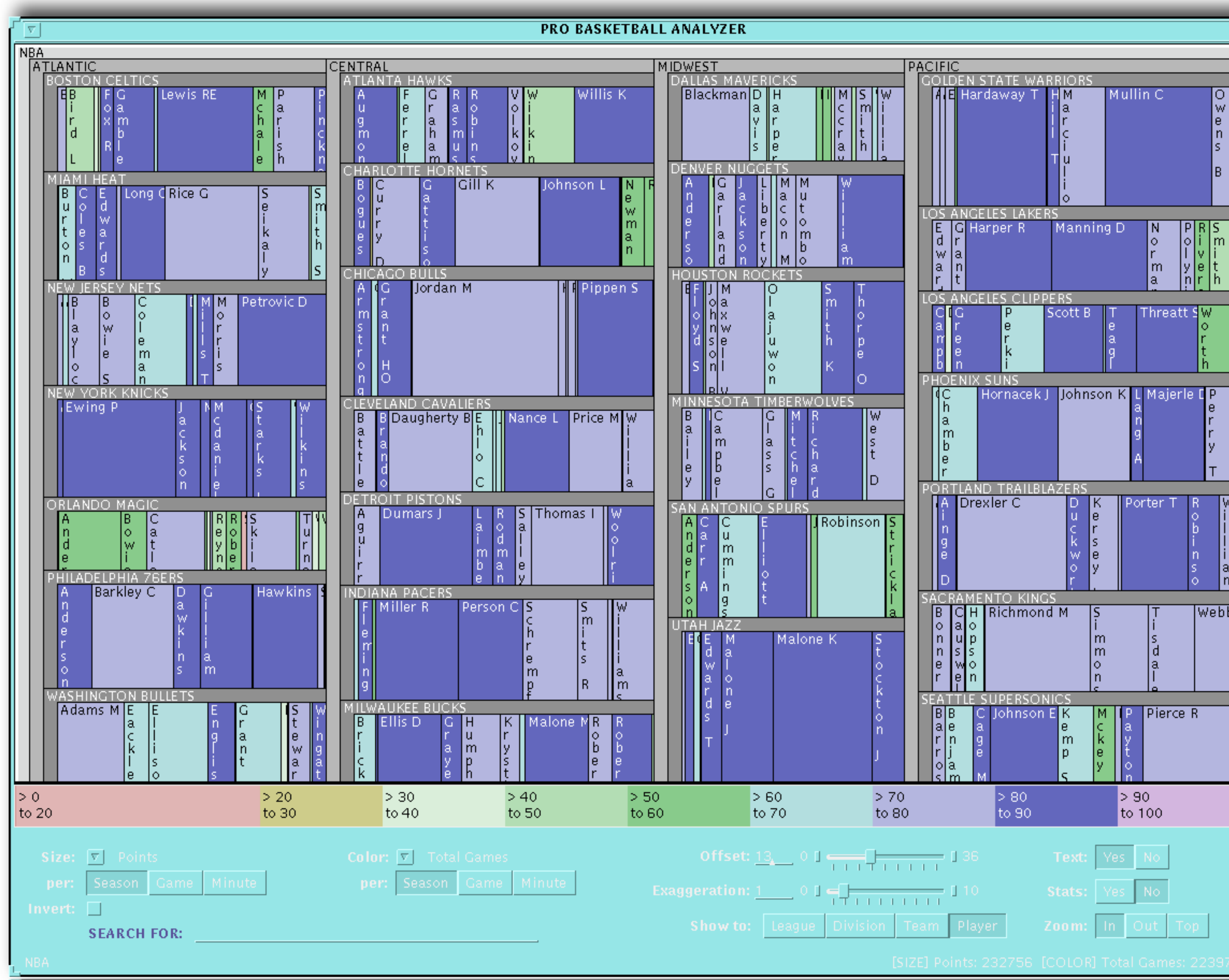
One Solution





[Shneiderman 1992; Johnson, 1993]

+ Space filling
+ Color coding
+ Size coding
– Requires learning



[Shneiderman 1992]

Treemaps: Layouts

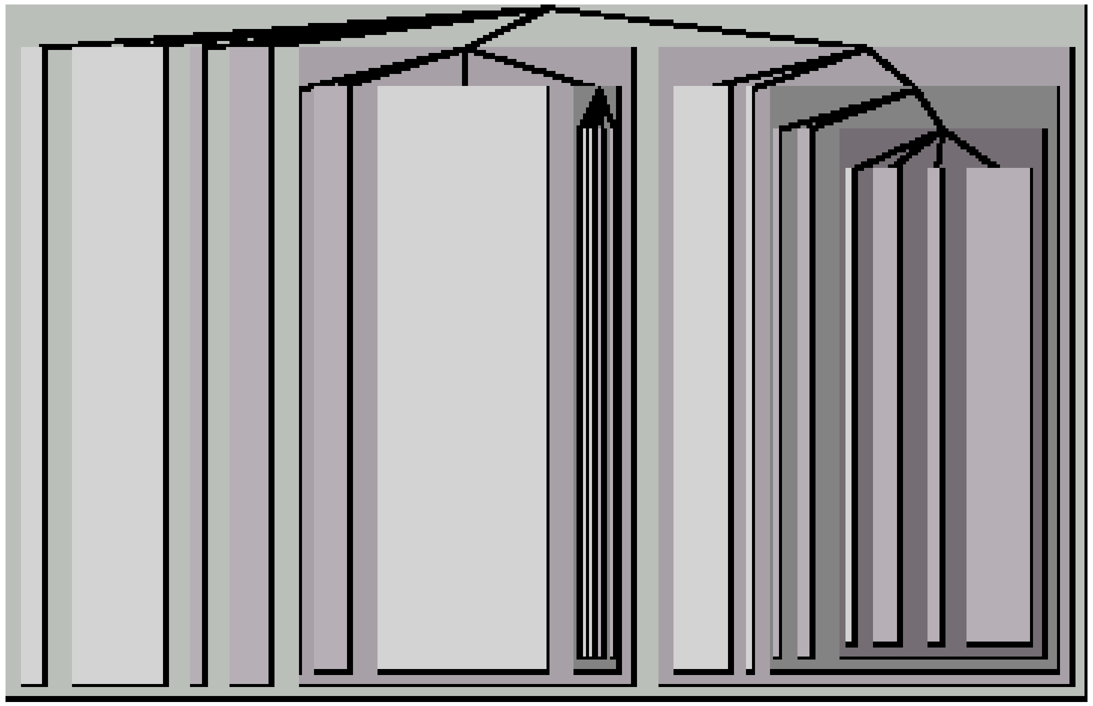


Figure 1: Top-Down, Size by Weight

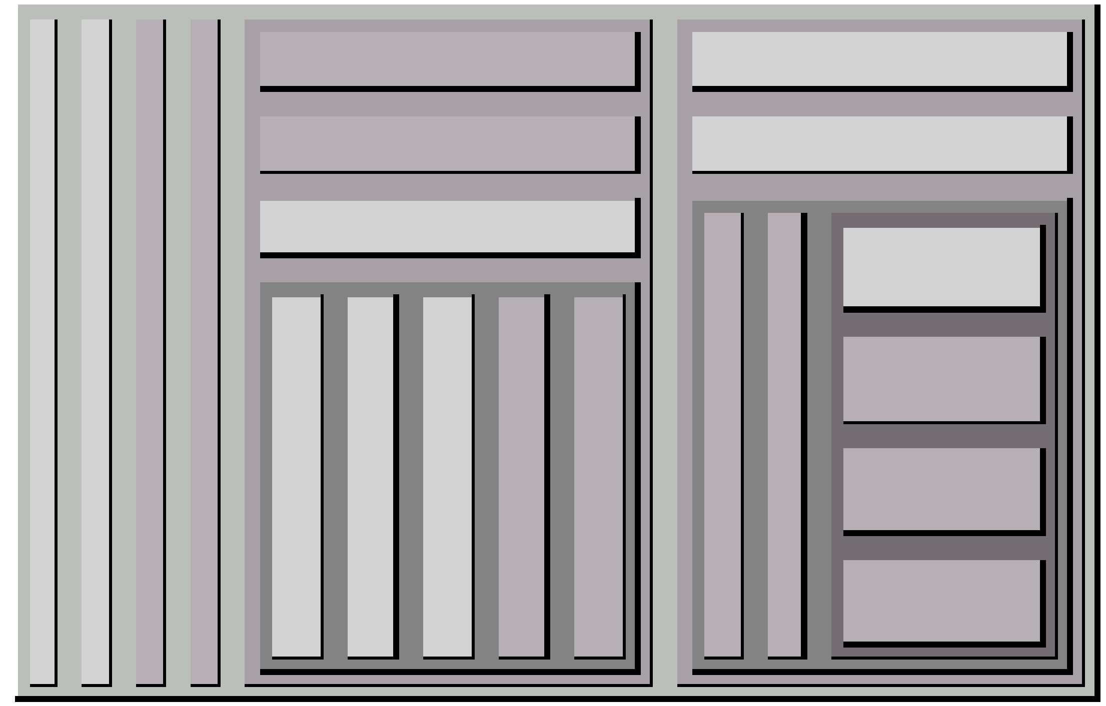


Figure 2: Slice-and-Dice, Size by Unit

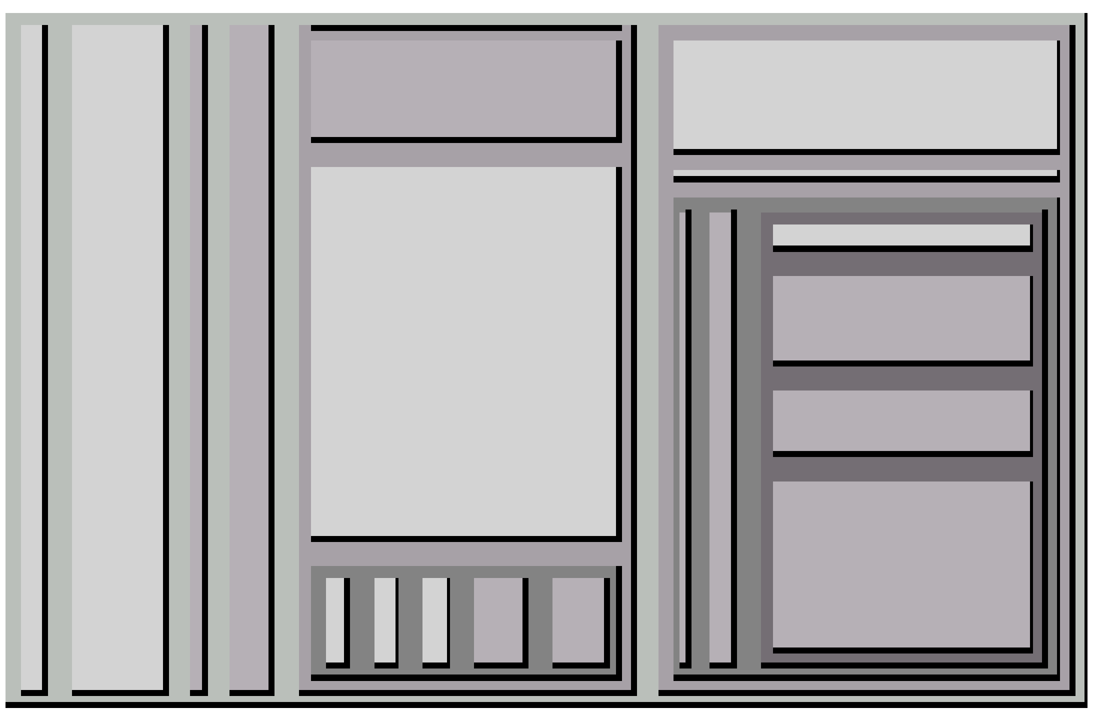


Figure 3: Slice-and-Dice, Size by Weight

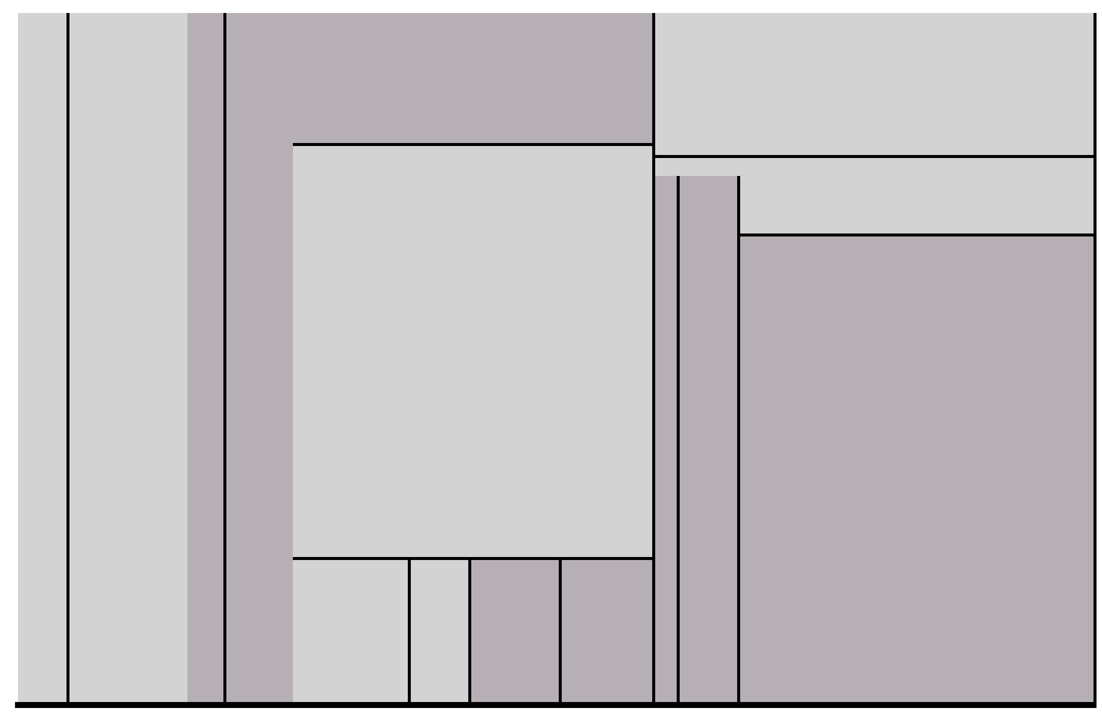


Figure 4: Slice-and-Dice, no offsets

[Shneiderman 1992; Johnson, 1993]

Treemaps Variants

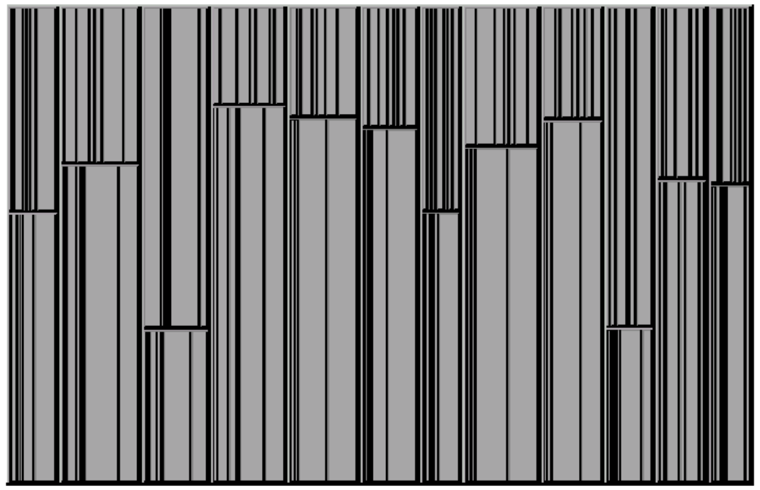
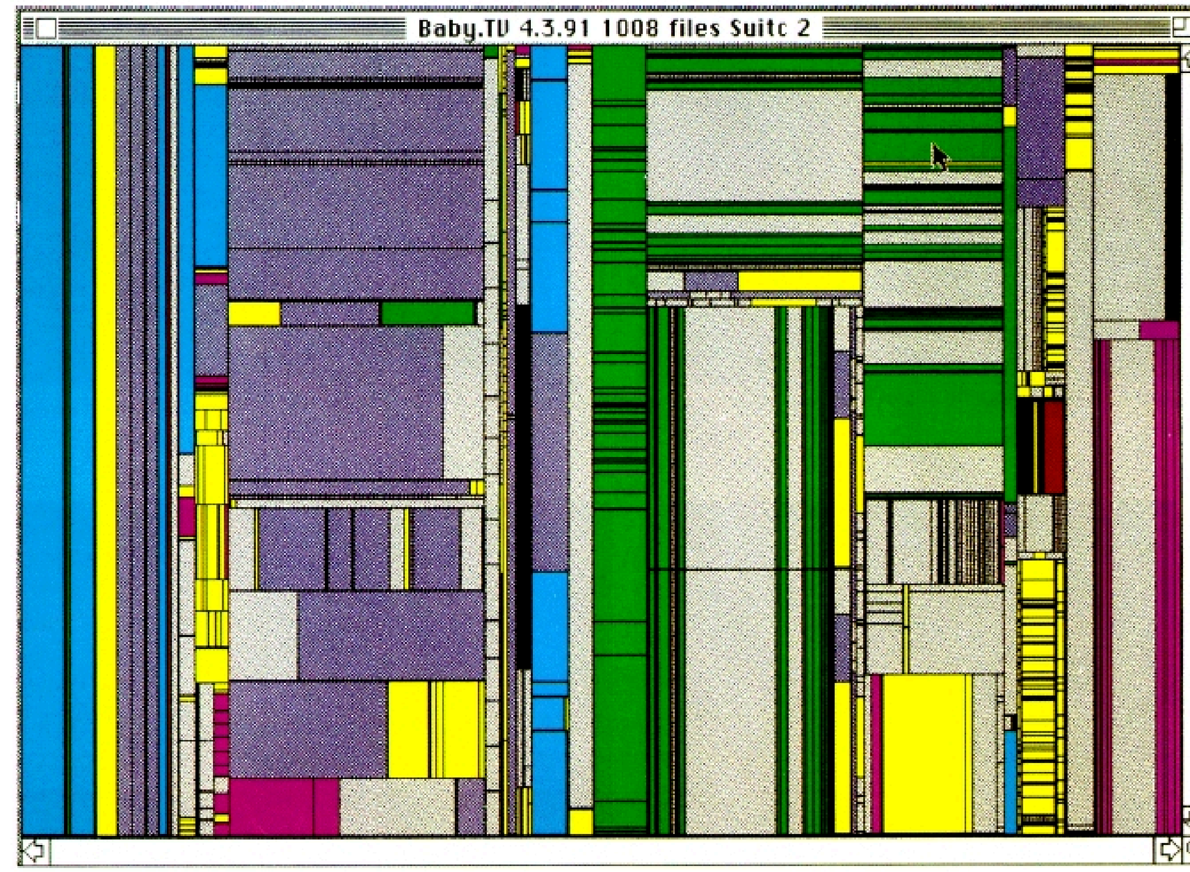


Figure 7: Treemap UNIX Experiment Results



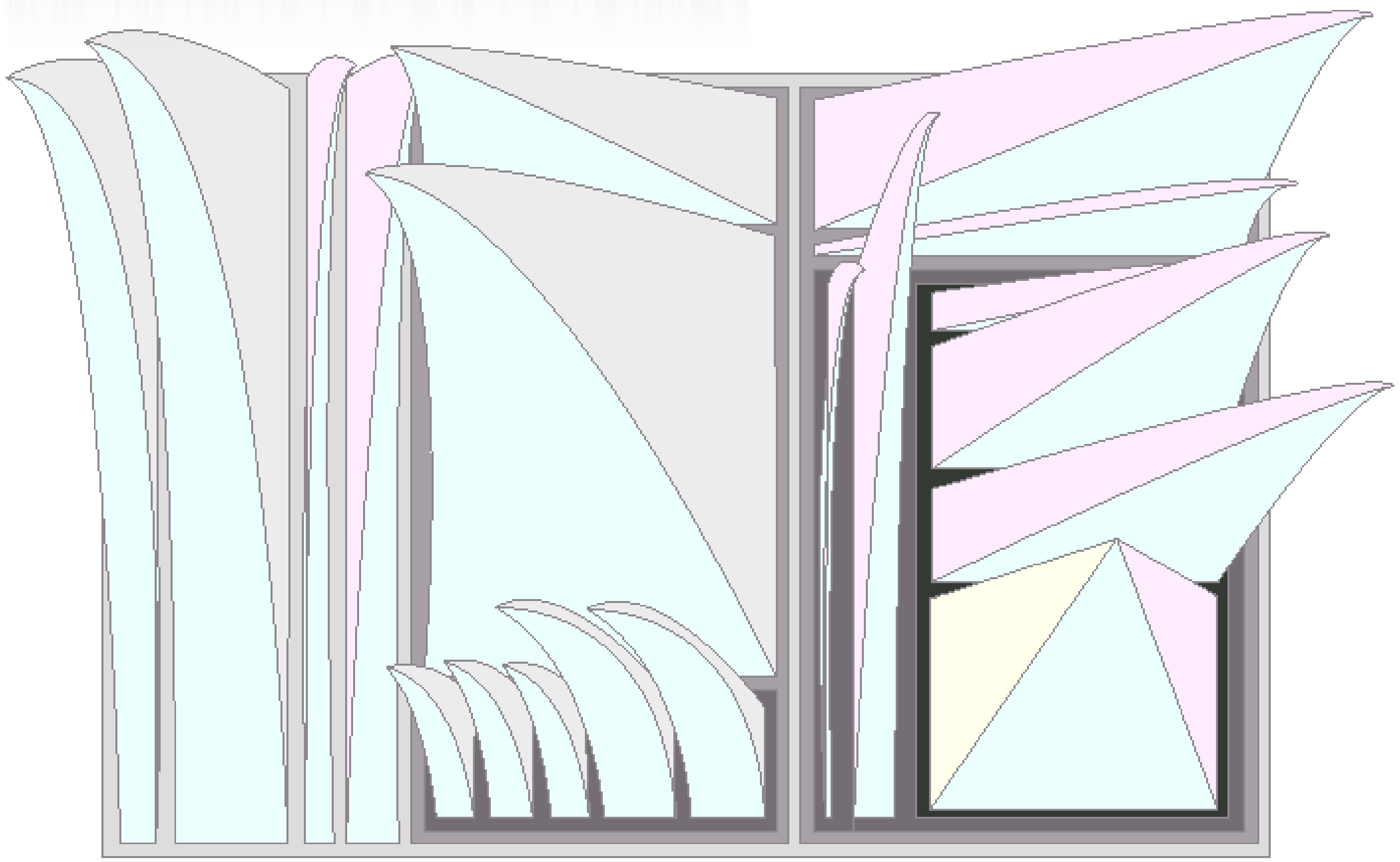
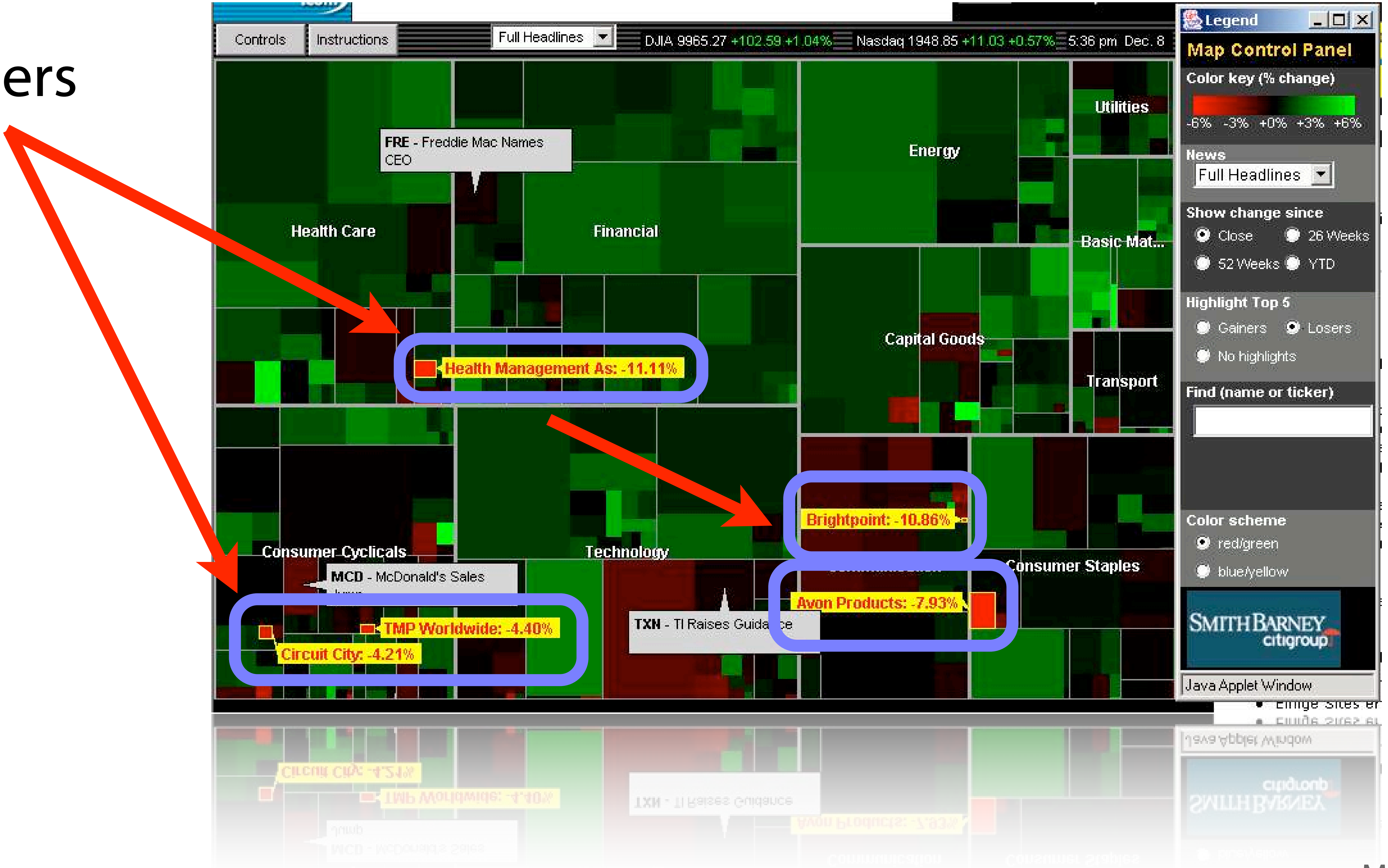


Figure 6: 2 1/2-D Treemaps

Treemaps: Finance Analysis

http://www.smartmoney.com

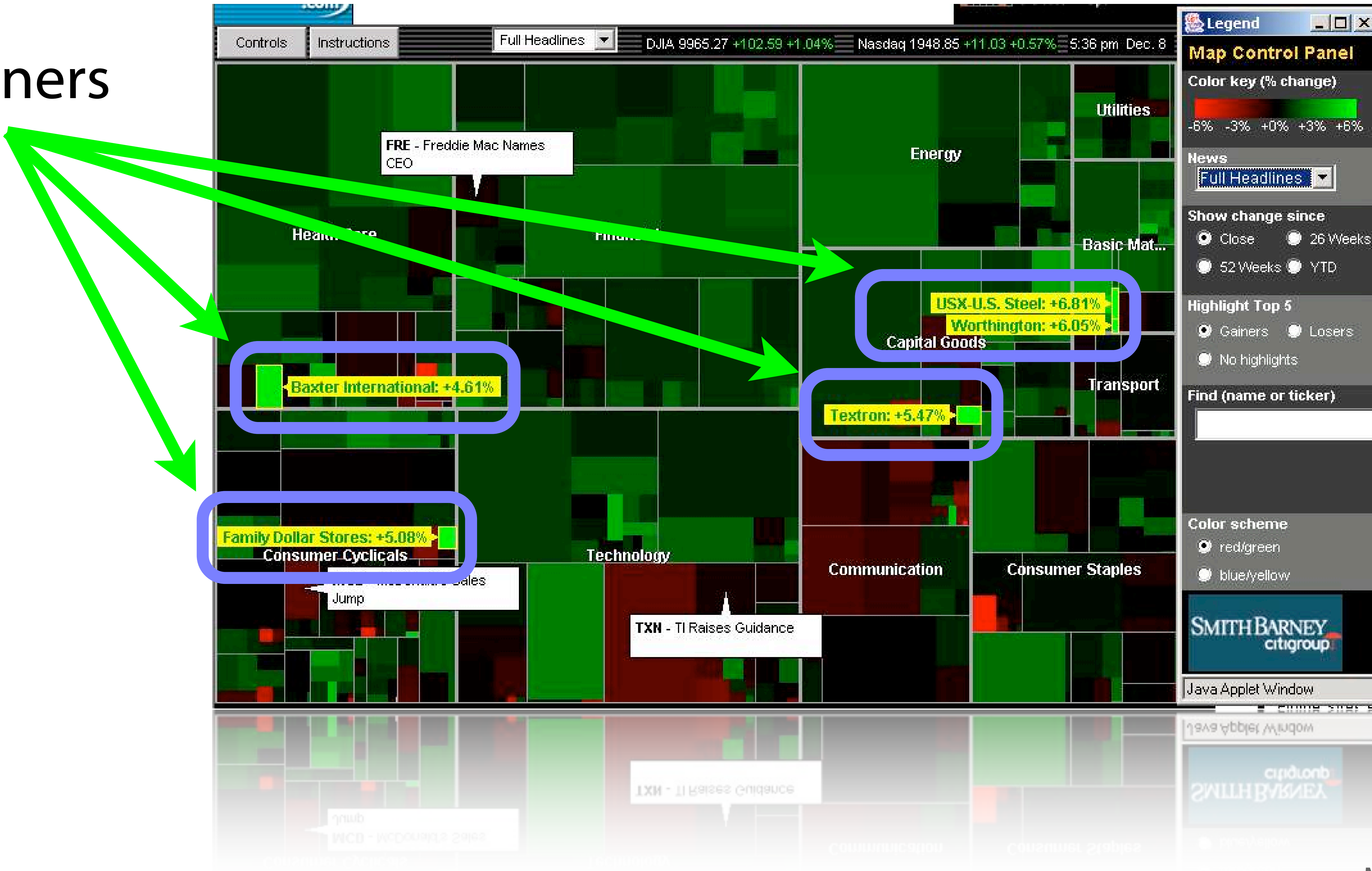
Losers



Treemaps: Finance Analysis

http://www.smartmoney.com

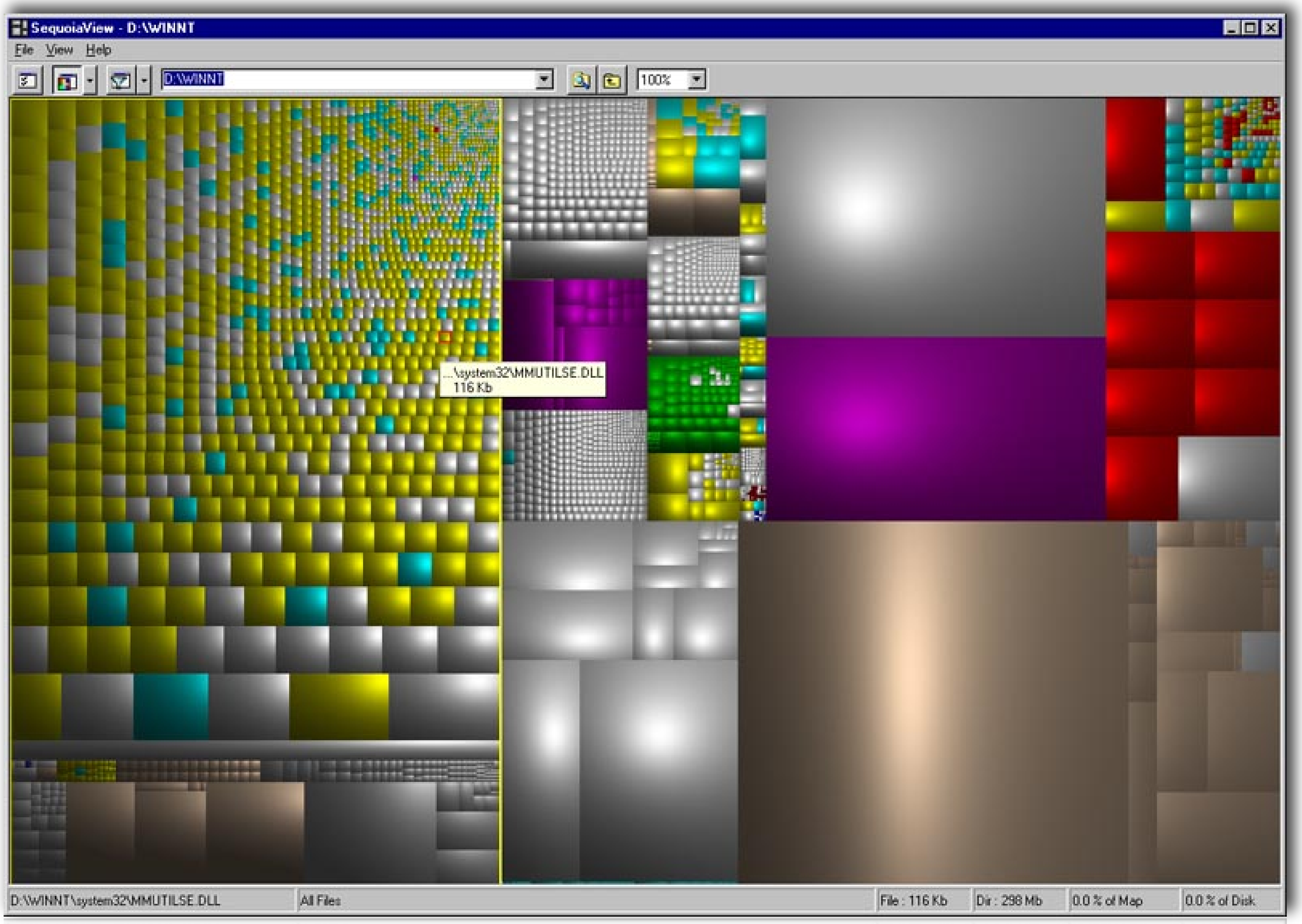
Gainers



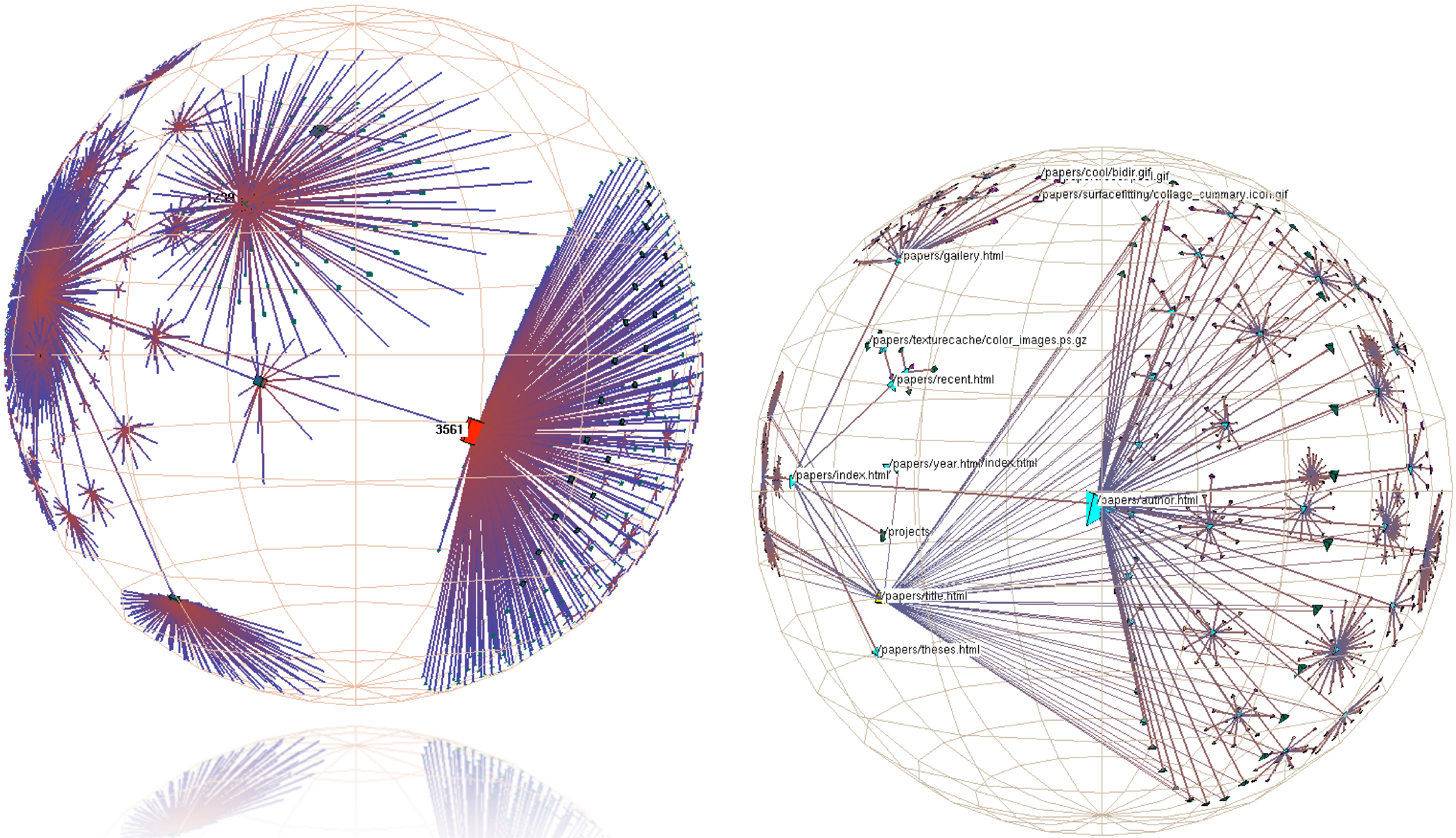
Treemap: Newsmap

http://www.win.tue.nl/sequoiaview/

Squarified Treemaps



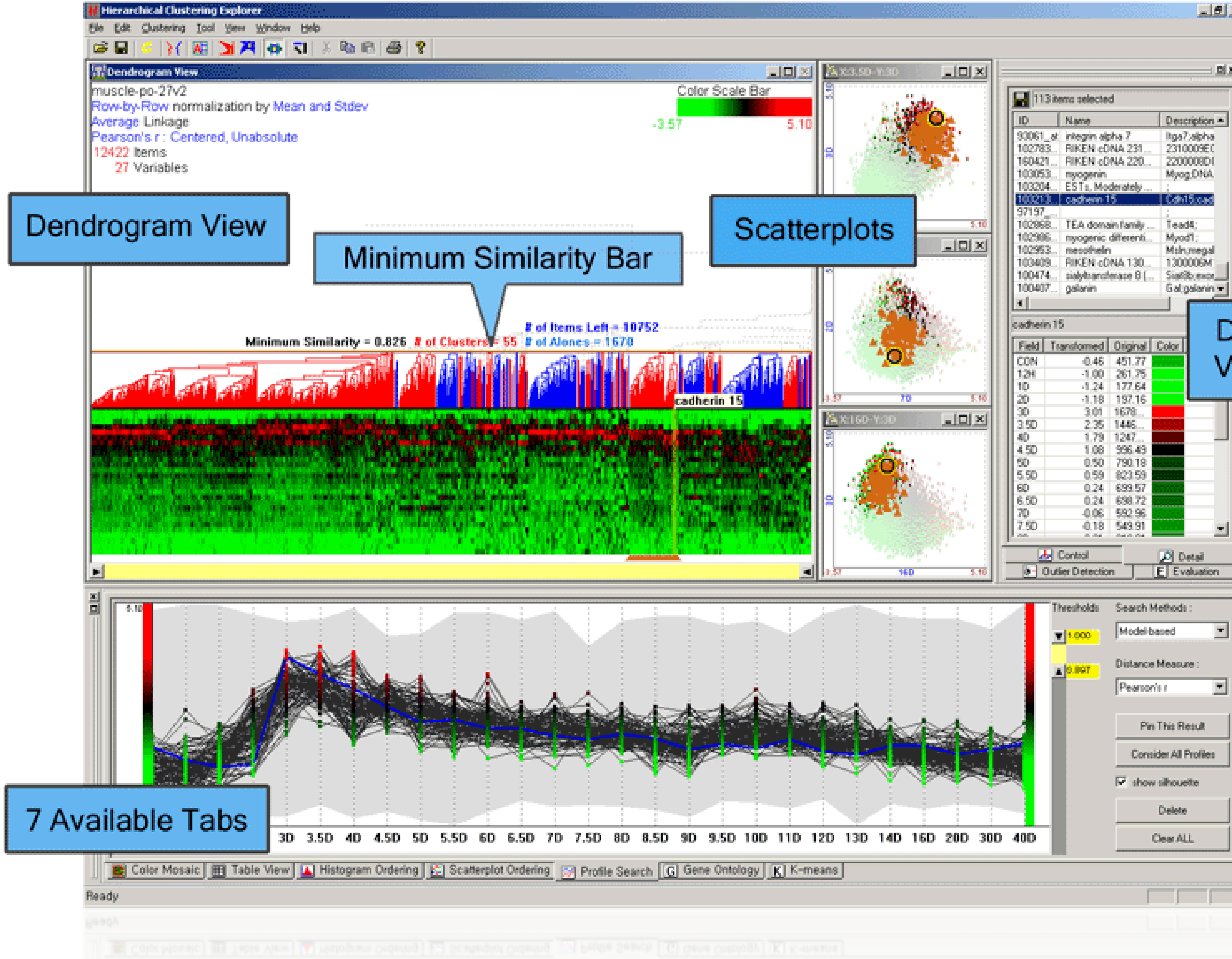
3D Hyperbolic Space



[Munzner, 1998]

for Interactive Exploration of Multidimensional Data

http://www.cs.umd.edu/hcil/multi-cluster



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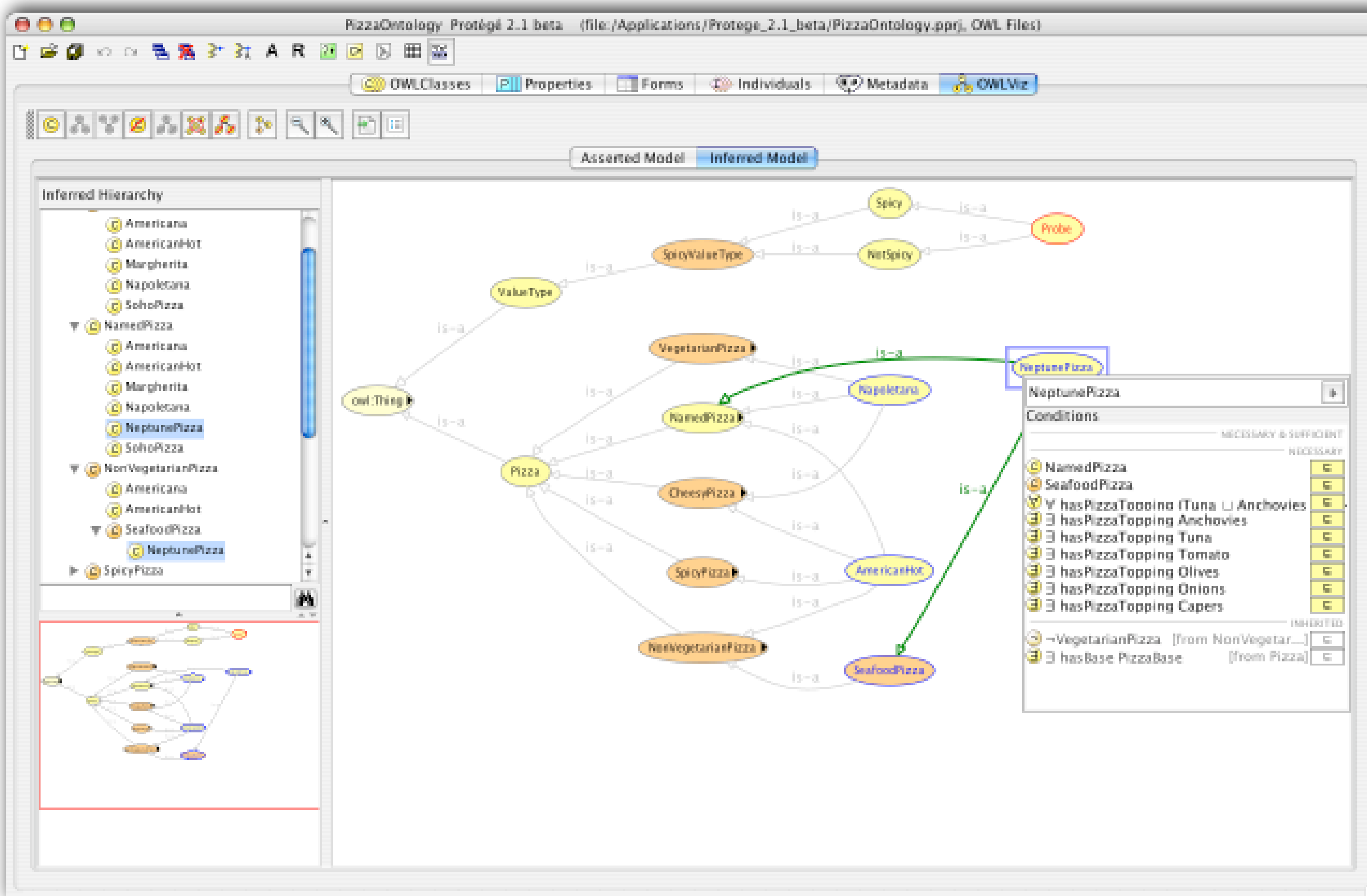
Protégé plug-ins

- **OntoViz** tab [7]
- **Jambalaya** [8]
- **TGViz** [9]
- **OWLViz** [10]



Ontology tools applying unconventional visualization techniques

- The **cluster map** [2] applied in **Autofocus** [1], **Spectacle** [2], the **DOPE** project [3], and **SWAP** [4].
- **Ontorama** [5] is a hyperbolic-style browser designed to render RDF files derived from a web-accessible ontology server called WEBKB-2 , which contains descriptions of over 74,500 object types from WORDNET
- **Ontobroker** [6] utilizes a hyperbolic tree view and is an ontology-based semantic indexing and instance querying technology for the WWW

Graph-based visualization tools:

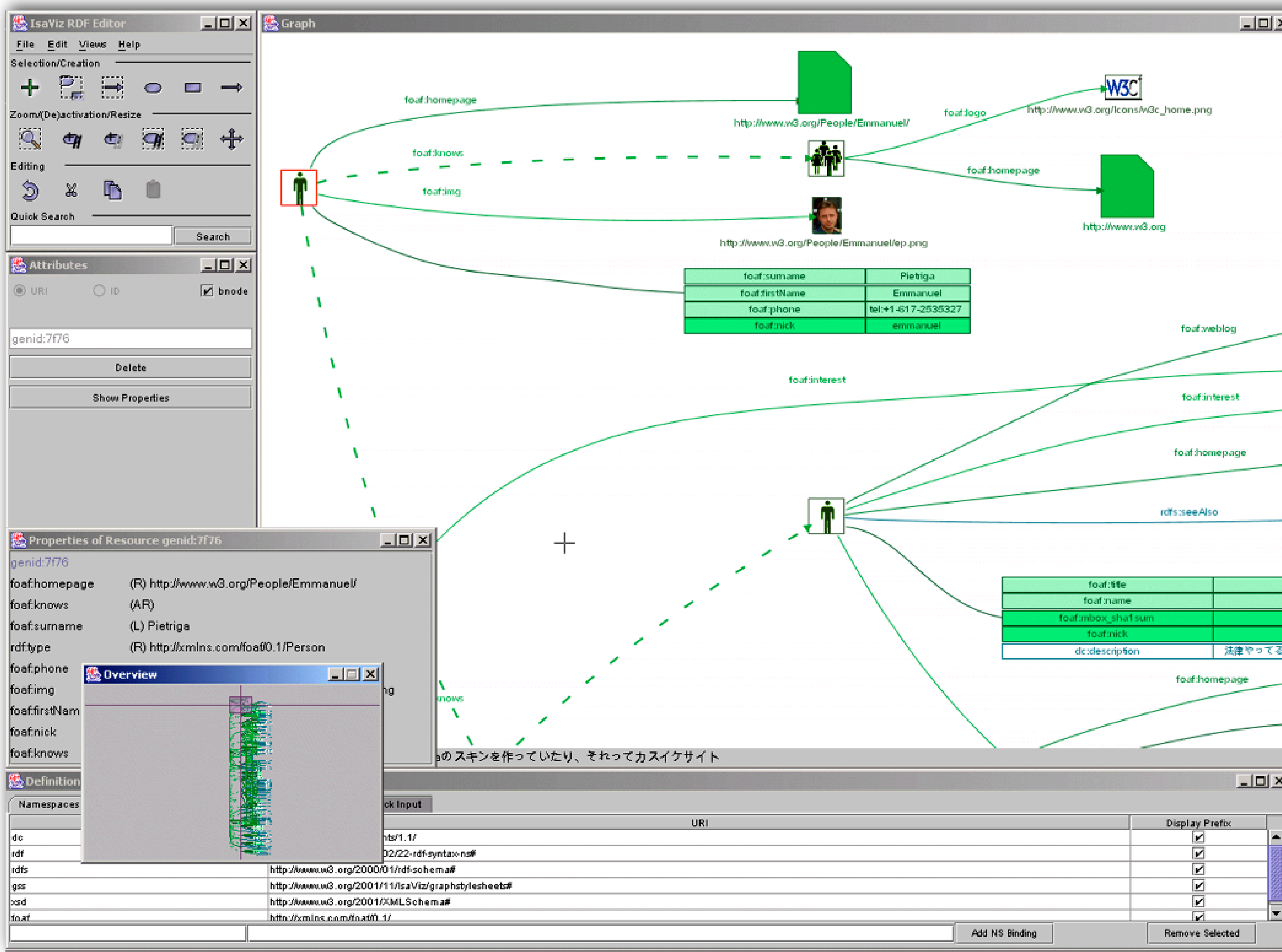
- **WebODE** [12] uses the tool called OntoDesigner to graphically edit ontologies using common node/edge to represent the concepts and the relations in a tree
- **Tadzebao** [13], which is a tool for collaborative development of ontologies, includes the tree-tool WebOnto
- **FCA** [14] uses simple node-link visualizations of the inherent structure
- **Conzilla** [15] and **VizCo** [16] apply RDF-graphs to create and manipulate ontologies
- **Vizigator** [17] represents topic maps using the **Touchgraph** technology [18]
- **ViSWeb** [19] is an OPM-based (Object-Process Methodology) layer on top of XML/RDF/OWL to express knowledge visually and in natural language

Graph-based visualization tools:

- **ORIENT** (Ontology engineering Environment) [20] is an Eclipse-based system using RDF-graphs and includes ontology building, mapping, evolution, evaluation and visualization.
- **RDFAuthor** [21] supports the creation of RDF instance data by dragging the data into a graph and binding it together using a graphical and quite simple interface.
- **FRODO RDFSViz** tool [24], which provides class models of ontologies represented in RDF Schema using GraphViz
- Building ontology-based queries with different levels of guidance is the aim of **GODE** [25] (Graphical Ontology Design Environment)

Graph-based visualization tools:

IsaViz [22] relies on **GraphViz** [23] to browse and author RDF models presented as graphs.

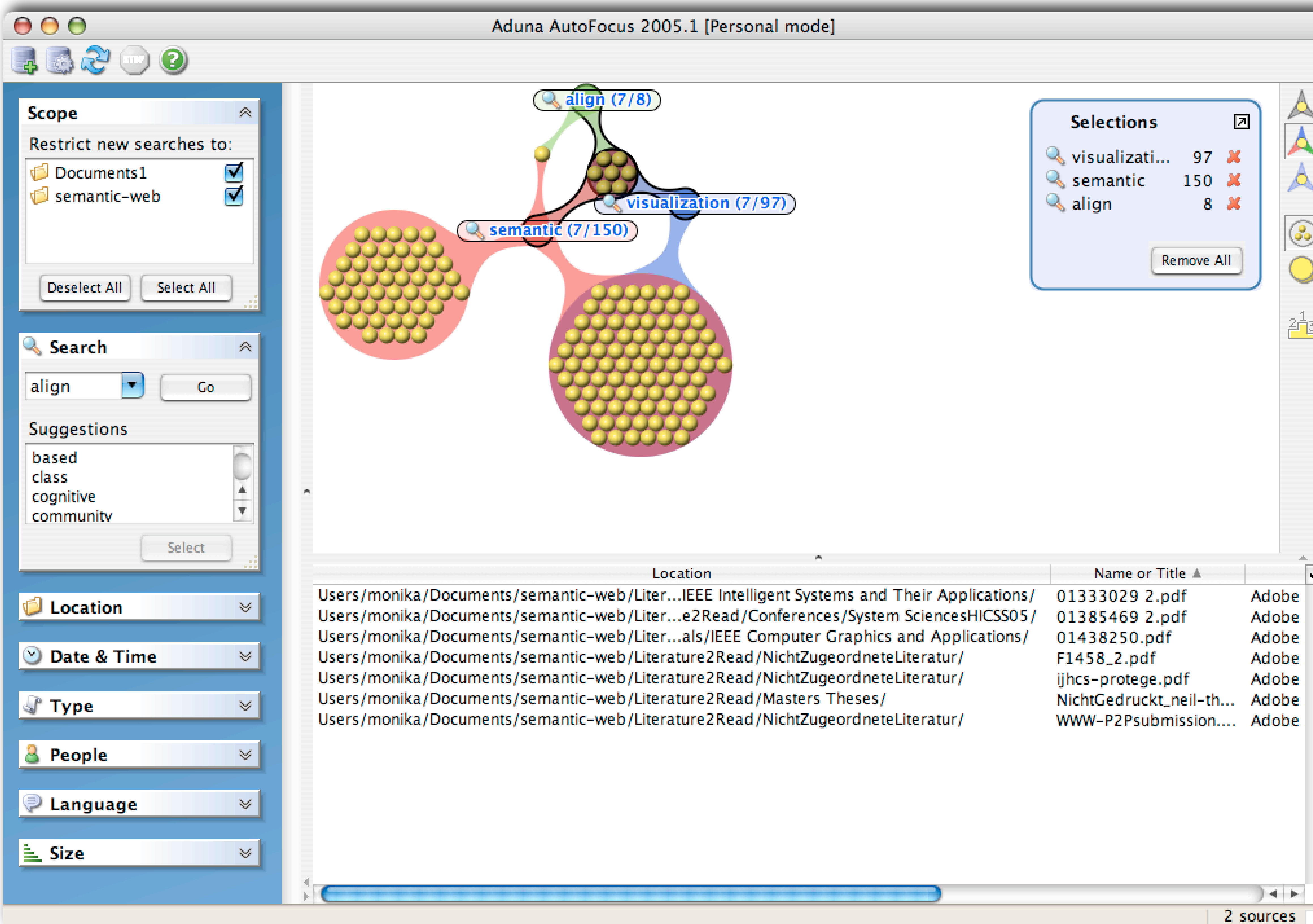


Visualization techniques support by:

- direct manipulation of the classifications / concepts / instances
- providing with overview
- appropriate presentation of semantically rich query results
- visual support for exploration and querying
- focus on structure (metadata) or on data: different points of view
- efficiently comparing ontologies
- supporting creation of ontologies based on standards

- Brings semantic, multi-dimensional information visualization (cluster map) to everyone's desktop
- Lets users oversee and access the overwhelming amount of information
- Integration of different sources: local files, emails, websites, intranet resources
- Using a local Sesame RDF Repository + Aduna Metadata Server for sharing Metadata in enterprise environments
- Metadata: file type, size, date, author(s), sender, keywords
- `http://www.aduna-software.com/home/overview.view`

Aduna AutoFocus



[1]

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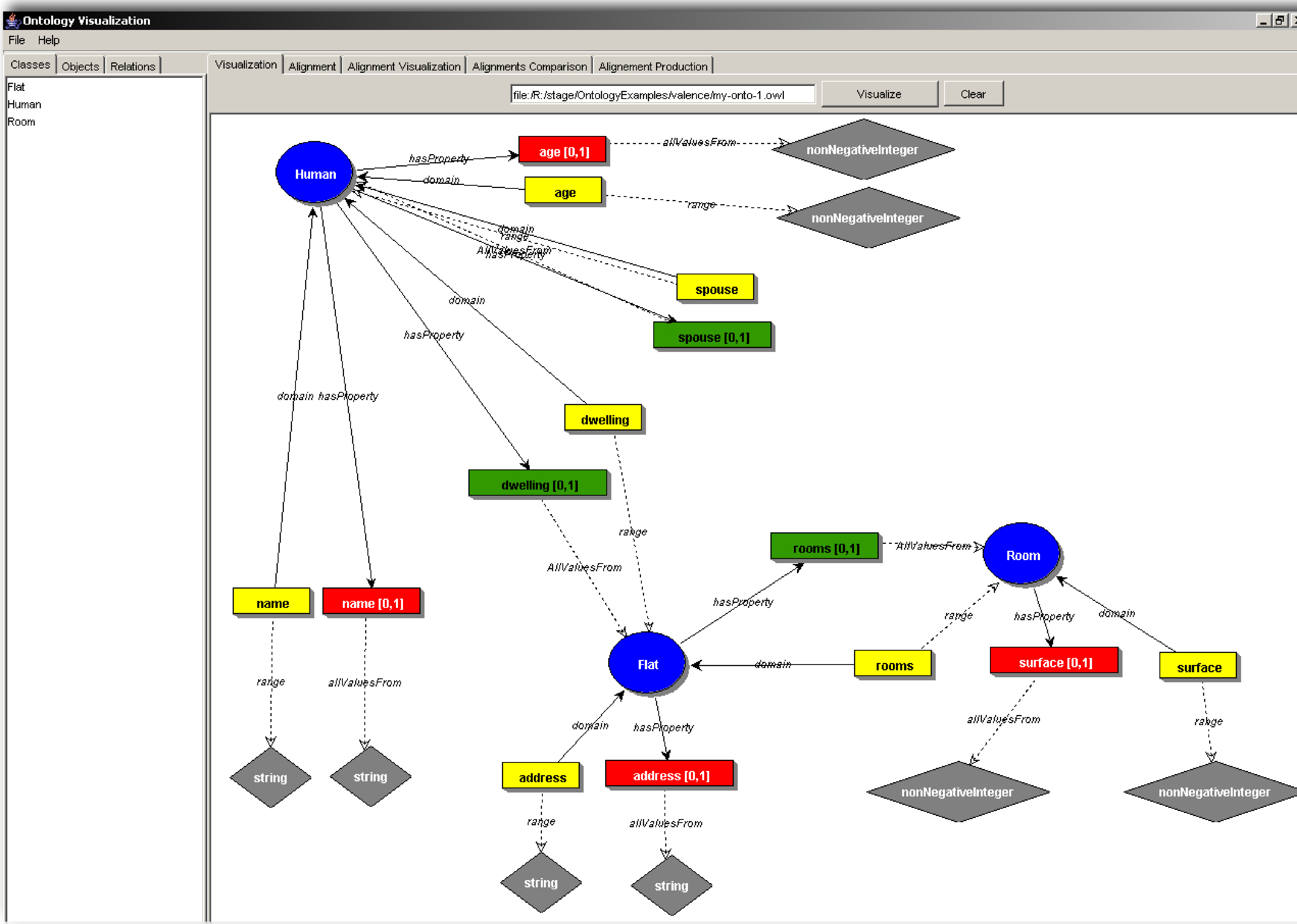
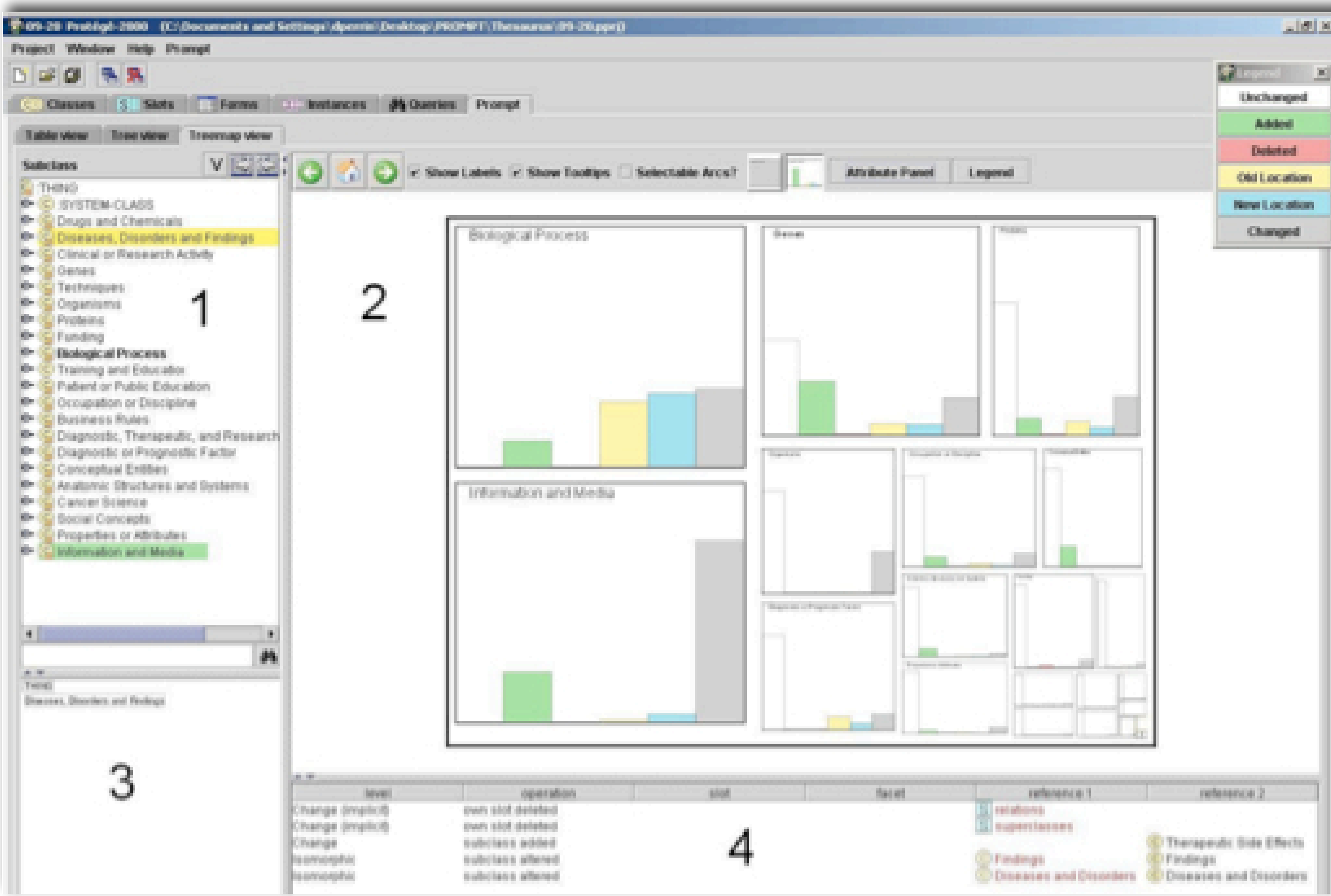
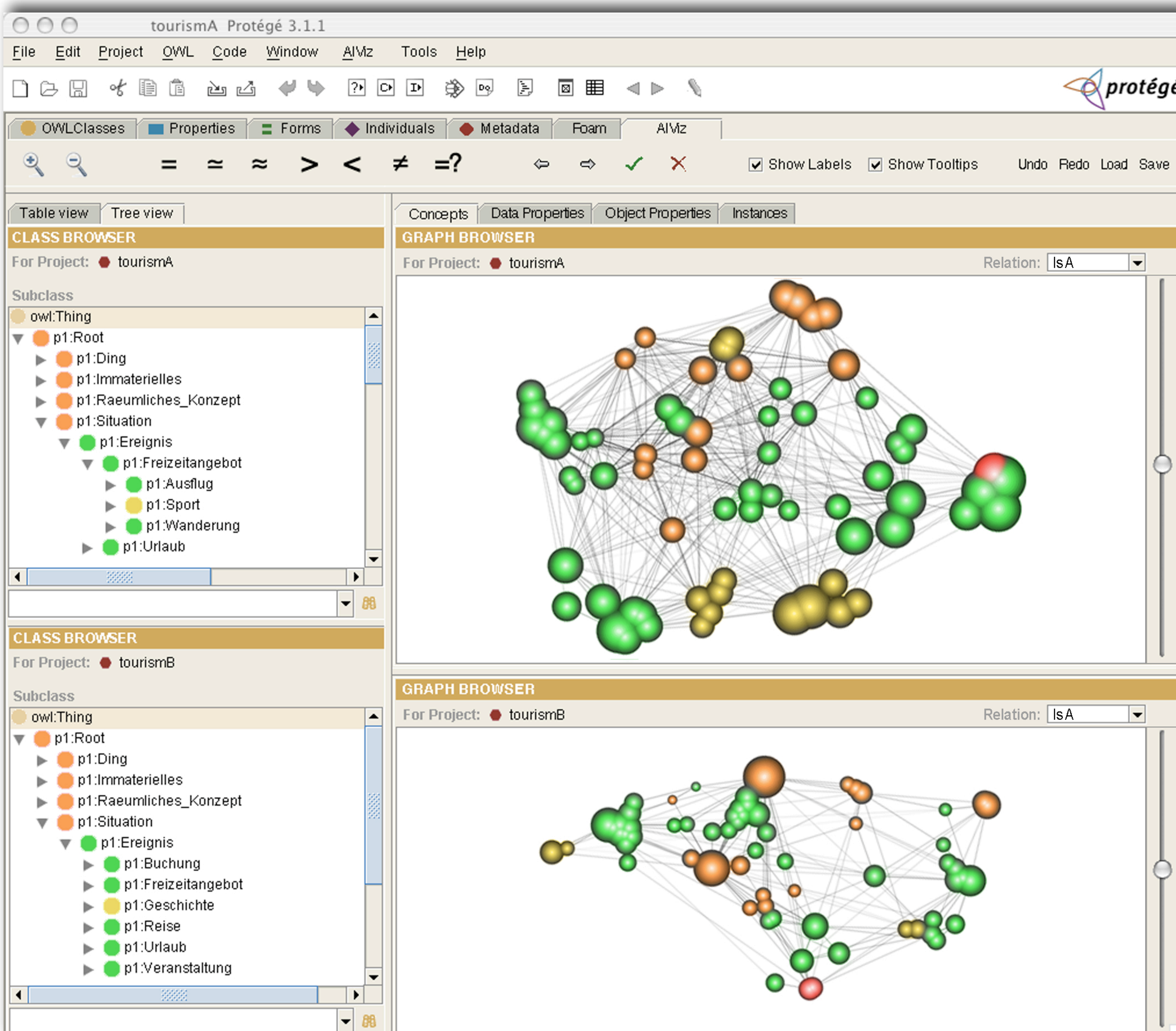
OLA Visualization




Project Window Help Prompt
Classes Slots Forms Instances Queries Prompt
Table view Tree view Treemap view
Subclass
THING
SYSTEM-CLASS
Drugs and Chemicals
Diseases, Disorders and Findings
Clinical or Research Activity
Genes
Techniques
Organisms
Proteins
Funding
Biological Process
Training and Education
Patient or Public Education
Occupation or Discipline
Business Rules
Diagnostic, Therapeutic, and Research
Diagnostic or Prognostic Factor
Conceptual Entities
Anatomic Structures and Systems
Cancer Science
Social Concepts
Properties or Attributes
Information and Media
1
2
3
4
Show Labels
Show Tooltips
Selectable Arcs?
Attribute Panel
Legend
Biological Process
Information and Media
Unchanged
Added
Deleted
Old Location
New Location
Changed
level
operation
slot
facet
reference 1
reference 2
Change (implicit)
Change (implicit)
Change
Isomorphic
Isomorphic
own slot deleted
own slot deleted
subclass added
subclass altered
subclass altered
relations
superclasses
Findings
Diseases and Disorders
Therapeutic Side Effects
Findings
Diseases and Disorders

AlViz



[Lanzenberger et al., 2006]

Alignment Tool Output


```
URI: http://meh/tourism2#Erlebnisurlaub Entity label: Erlebnisurlaub URI: http://meh/
tourism1#Erholungsurlaub Entity label: Erholungsurlaub Confidence = 0.547619047619048 Syntactic
similarity: 0.6428571428571429 Similar Superclasses: 1.0 Similar Class Object Properties To:
1.0000000000000022 Correct Value = 0
URI: http://meh/tourism2#Erlebnisurlaub Entity label: Erlebnisurlaub URI: http://meh/tourism1#Aktivurlaub
Entity label: Aktivurlaub Confidence = 0.4545454545454545486 Syntactic similarity: 0.3636363636363636365
Similar Class Object Properties To: 1.0000000000000022 Correct Value = 1
URI: http://meh/tourism2#Erlebnisurlaub Entity label: Erlebnisurlaub URI: http://meh/
tourism1#Kremserfahrt Entity label: Kremserfahrt Confidence = 0.29584910972503153 Syntactic similarity:
0.1666666666666666 Similar Superclasses: 0.44176132501685367 Similar Class Object Properties To:
1.0000000000000022 Correct Value = 0
URI: http://meh/tourism2#Erlebnisurlaub Entity label: Erlebnisurlaub URI: http://meh/tourism1#Schwimmen
Entity label: Schwimmen Confidence = 0.16666666666666705 Similar Class Object Properties To:
1.0000000000000022 Correct Value = 0
URI: http://meh/tourism1#Immaterielles Entity label: Immaterielles URI: http://meh/tourism2#Immaterielles
Entity label: Immaterielles Confidence = 1.0 Syntactic similarity: 1.0 Similar Class Object Properties
To: 1.0000000000000022 Correct Value = 1
URI: http://meh/tourism1#Immaterielles Entity label: Immaterielles URI: http://meh/tourism2#Situation
Entity label: Situation Confidence = 0.47256039045316767 Similar Superclasses: 1.0 Similar Subclasses:
0.8353623427190036 Similar Class Object Properties To: 1.0000000000000022 Correct Value = 0
URI: http://meh/tourism1#Immaterielles Entity label: Immaterielles URI: http://meh/
tourism2#Raeumliches_Konzept Entity label: Raeumliches_Konzept Confidence = 0.35915492957727985 Similar
Superclasses: 1.0 Similar Subclasses: 0.15492957746367686 Similar Class Object Properties To:
1.0000000000000022 Correct Value = 0
```

OWL Ontology Construct	Comparison Relationship	Description
Concept	Equal	URI's equal.
		Class member instances equal.
	Syntactically equal	Labels are the same.
	Similar	Superclasses are the same.
		Subclasses are the same.
		Data properties are the same.
		Object properties are the same.
		Similar low/high fraction of instances.
	Broader than	Subclass superclass comparison.
	Narrower than	Superclass subclass comparison.
	Different	Class is different from all classes of the second ontology.

[Lanzenberger et al., 2006]

- Read / assess / correct alignment result
- Examine the context of entities for both source ontologies
- Manipulate source ontologies (change labels, URIs, etc.)

[Lanzenberger et al., 2006]

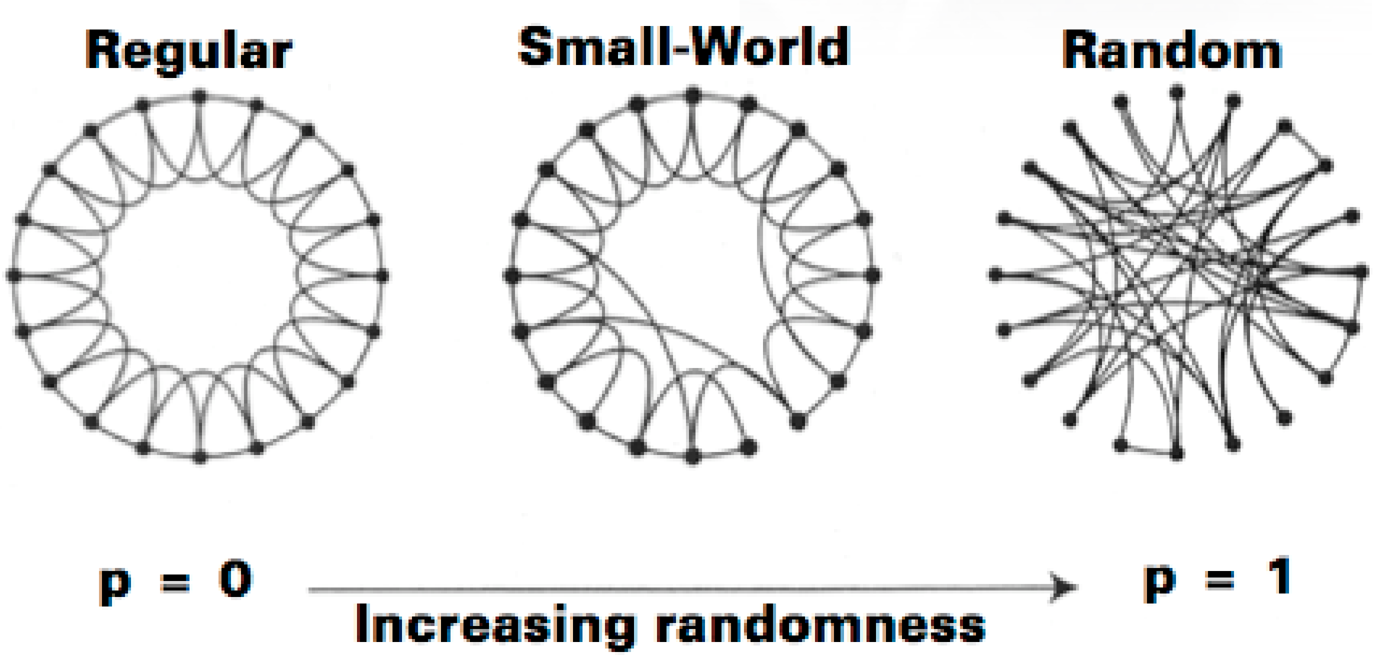
- Neither completely regular nor completely random: Regular graphs 'rewired' to introduce increasing amounts of disorder
- Two characteristic features: clustering coefficient high and average path length short
- Variety of edge lengths, with shorter lengths for edges in tight clusters , longer lengths for random edges between clusters

[Watts & Strogatz, 1998]

Small World Graphs

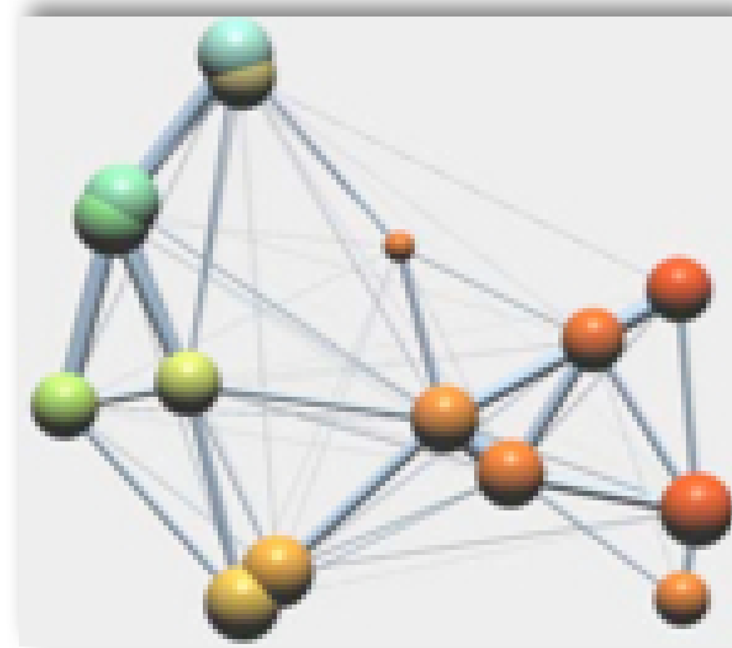
Small-world phenomemon: according to Milgram each actor in a social network is linked to any other with a maximum of 6 intermediaries. Experiment in 1967 suggested that two random US citizens were connected on average by a chain of six acquaintances.

Smaller communities, such as mathematicians, are densely connected: Mathematicians use the Erdös number to describe their distance from Paul Erdös based on their shared publications.
The Erdös Number Project:
`http://www.oakland.edu/enp/`



[Milgram, Case]

- Based on a spring-embedded algorithm that position tightly coupled groups of nodes closely together and loosely coupled groups of nodes far apart
- Uses clusters to group the nodes of a graph according to the selected level of detail (degree of abstraction DOA $\in$ [0, 1])



- Distance between two clusters of nodes is inversely proportional to their coupling (LinLog)
- Average link uses the average distance between all members

All spring-embedded algorithms bear the problem of high computational complexity - usually $O(N^3)$, Optimization: $O(N^2 \, Log(N))$

Clustering the graph improves program's interactivity: On average there are only O(Log(N)) clusters visible

Users' Goals:

- Are there any distinct groups of items that are strongly interconnected (i.e. graph clusters)?
- How do these split into separate clusters?
- How do these clusters relate?

[van Ham, et al. 2004]

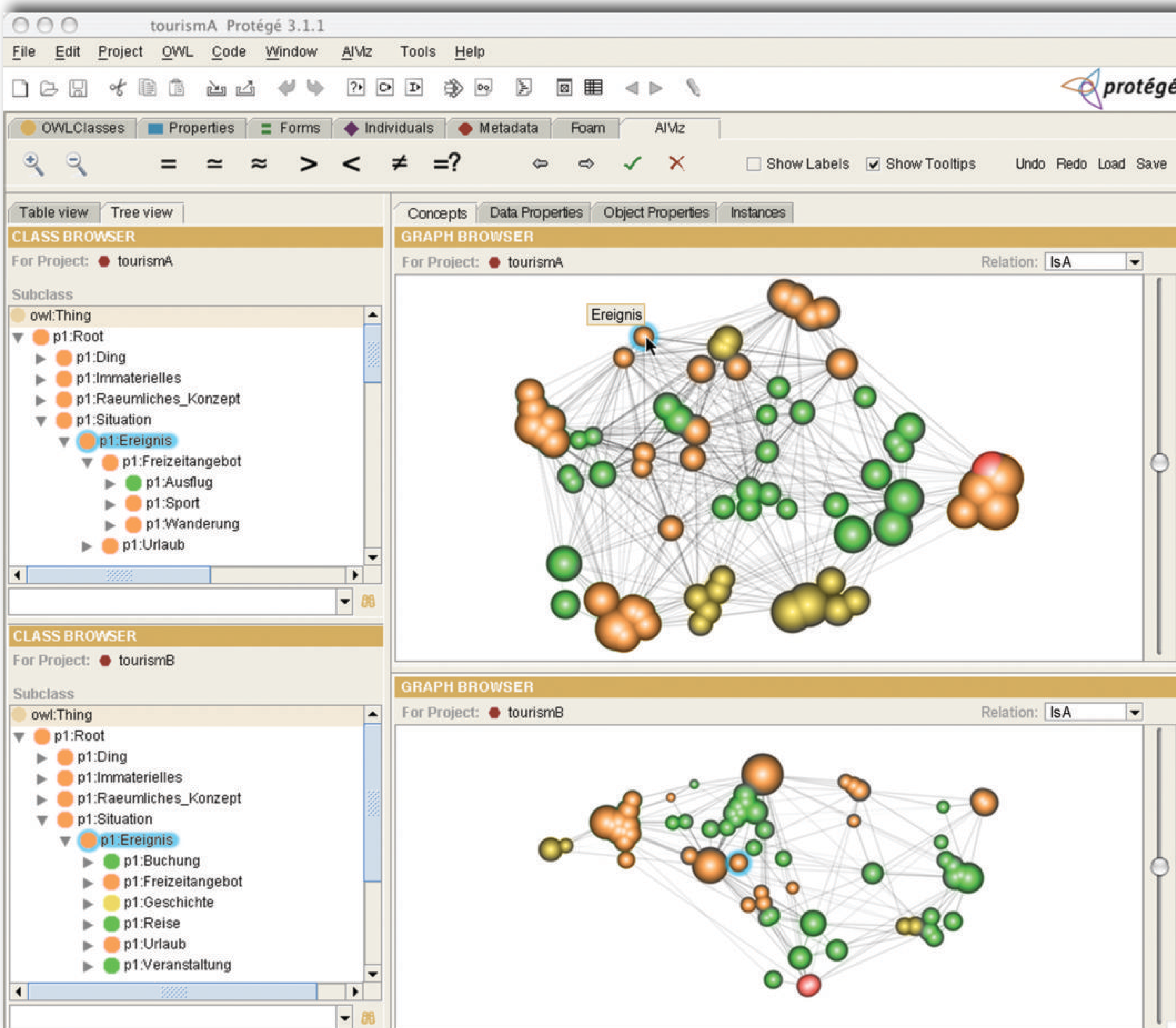
- Tab widget plug-in for Protégé 3.2
- AlViz links four views in order achieve a better integration of overview and details
- Represents the entities linked together according to selected mutual properties such as `IsA`, `IsPart`, `IsMember`, `locatedIn`, `hasOwner`, `isMadeBy`, `...`
- Color encodes alignment type

[Lanzenberger et al., 2006]

- Reduced saturation indicates mixed clusters
- Different levels of detail (degree of abstraction)
- Shape and size of cluster represents number of nodes
- Implementation: 2D graphs
  (based on implementation from Stephen Ingram)

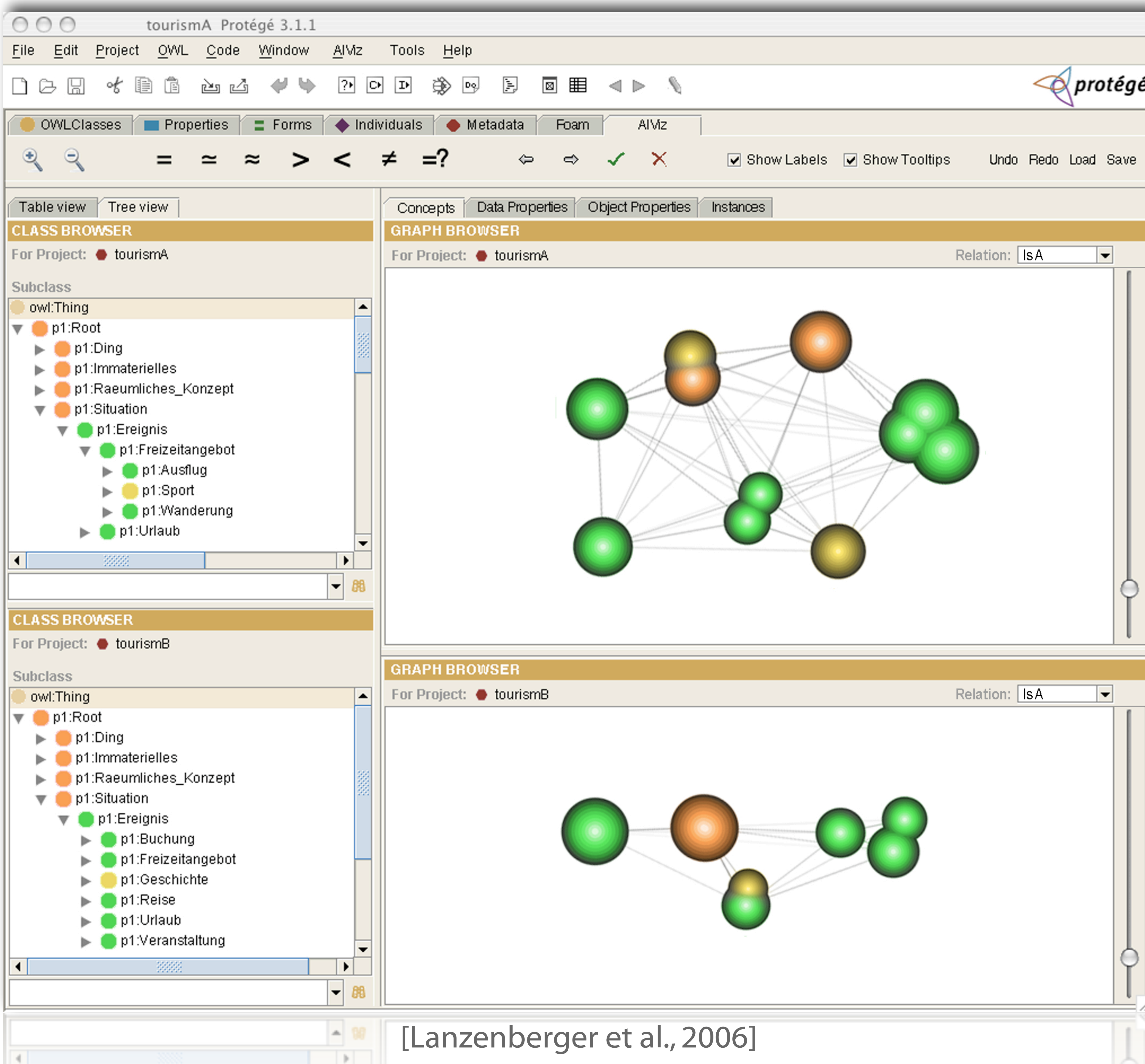
[Lanzenberger et al., 2006]

AlViz

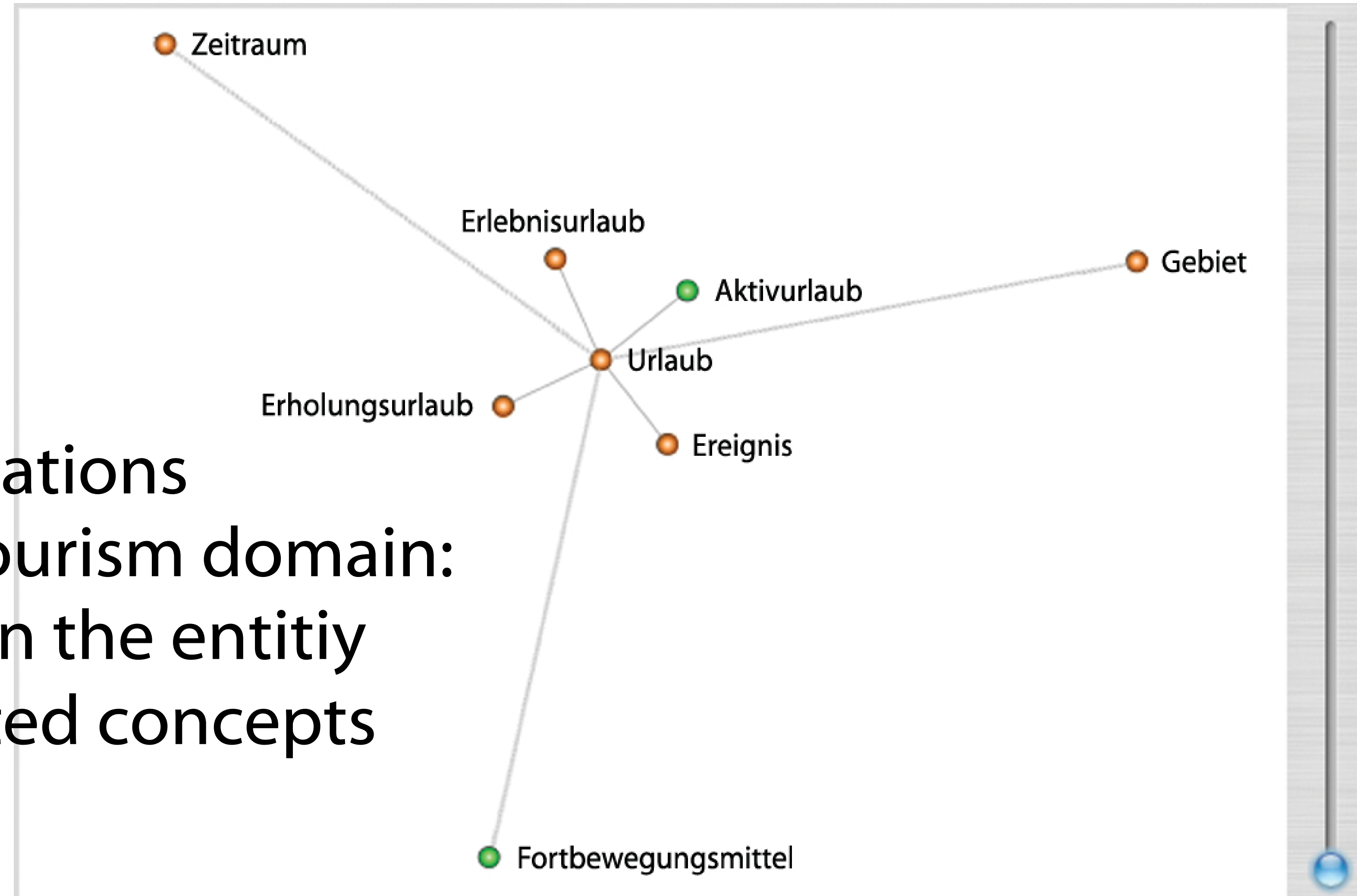


[Lanzenberger et al., 2006]

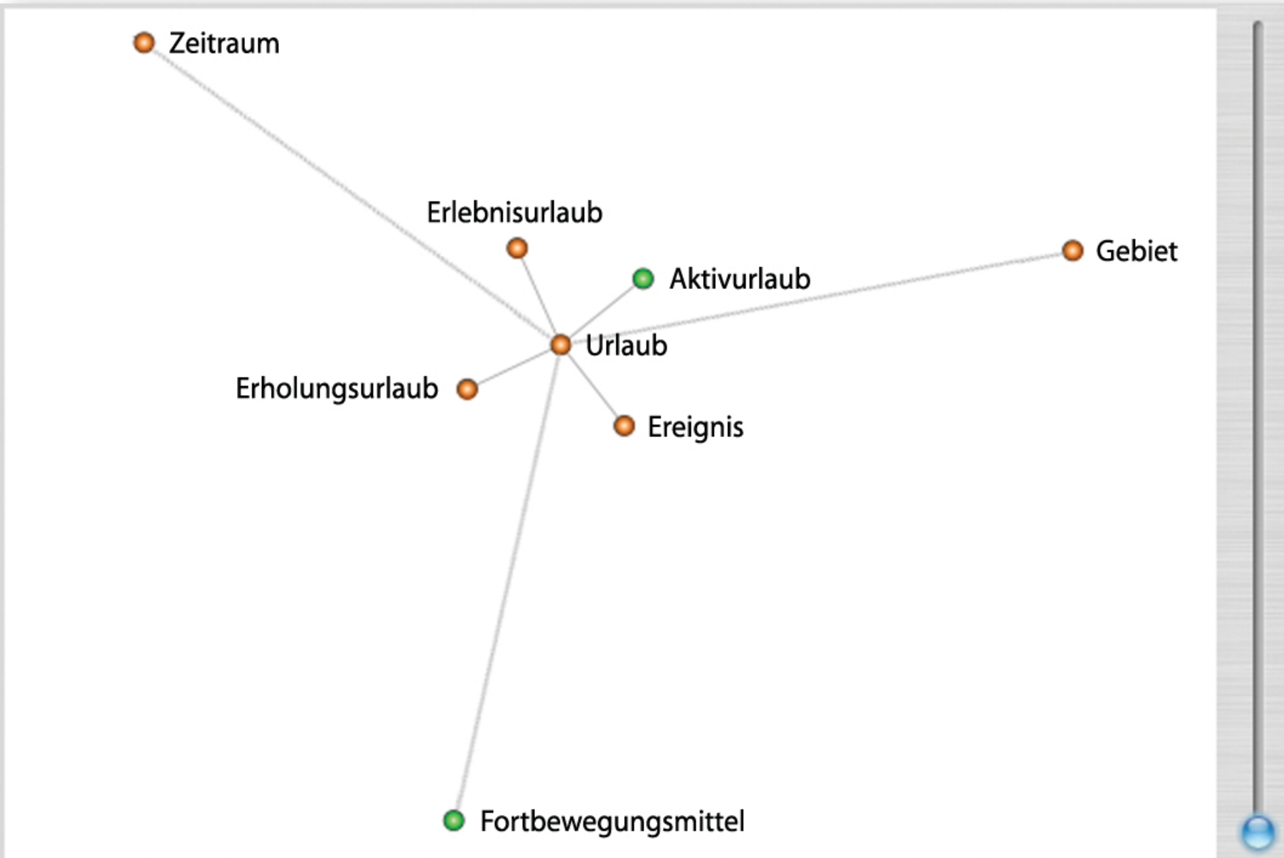
AlViz

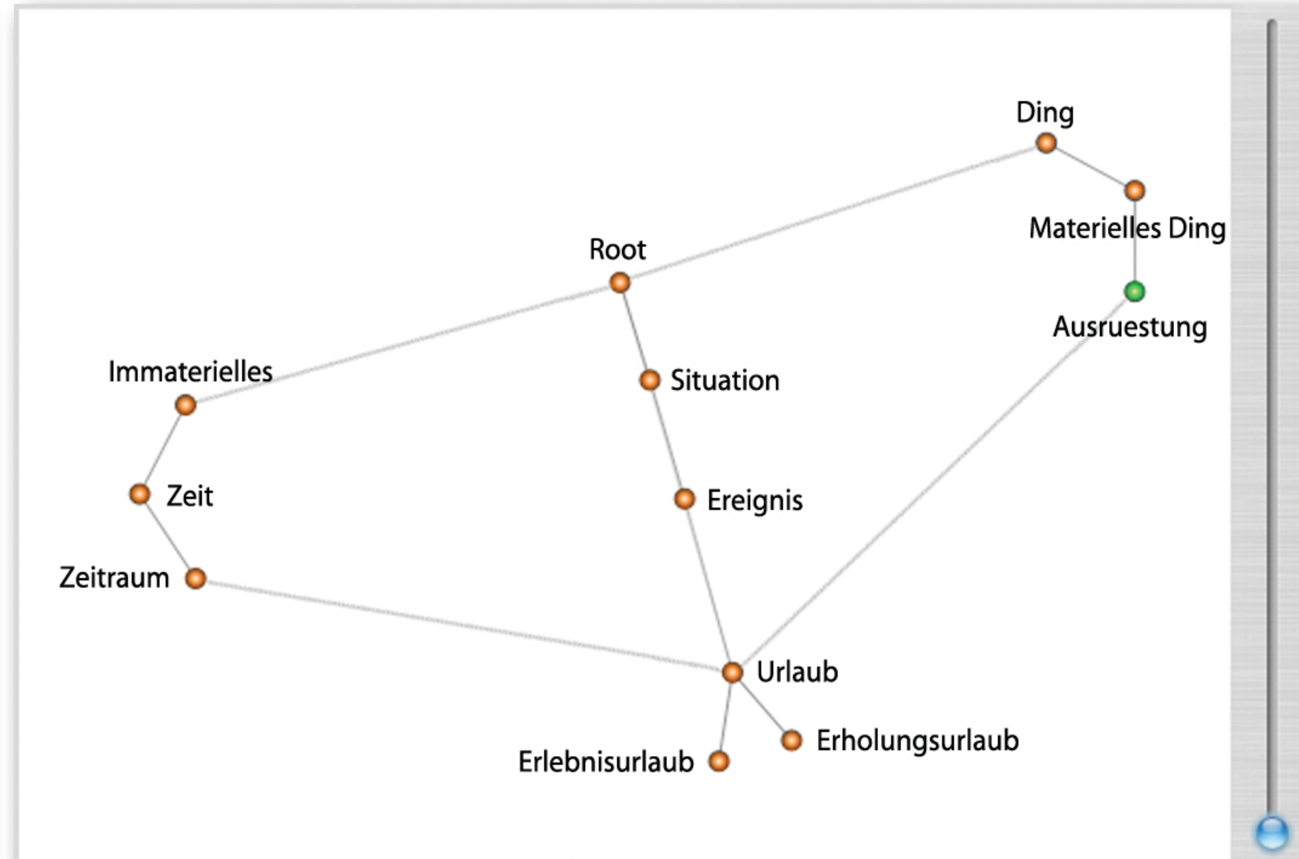


[Lanzenberger et al., 2006]



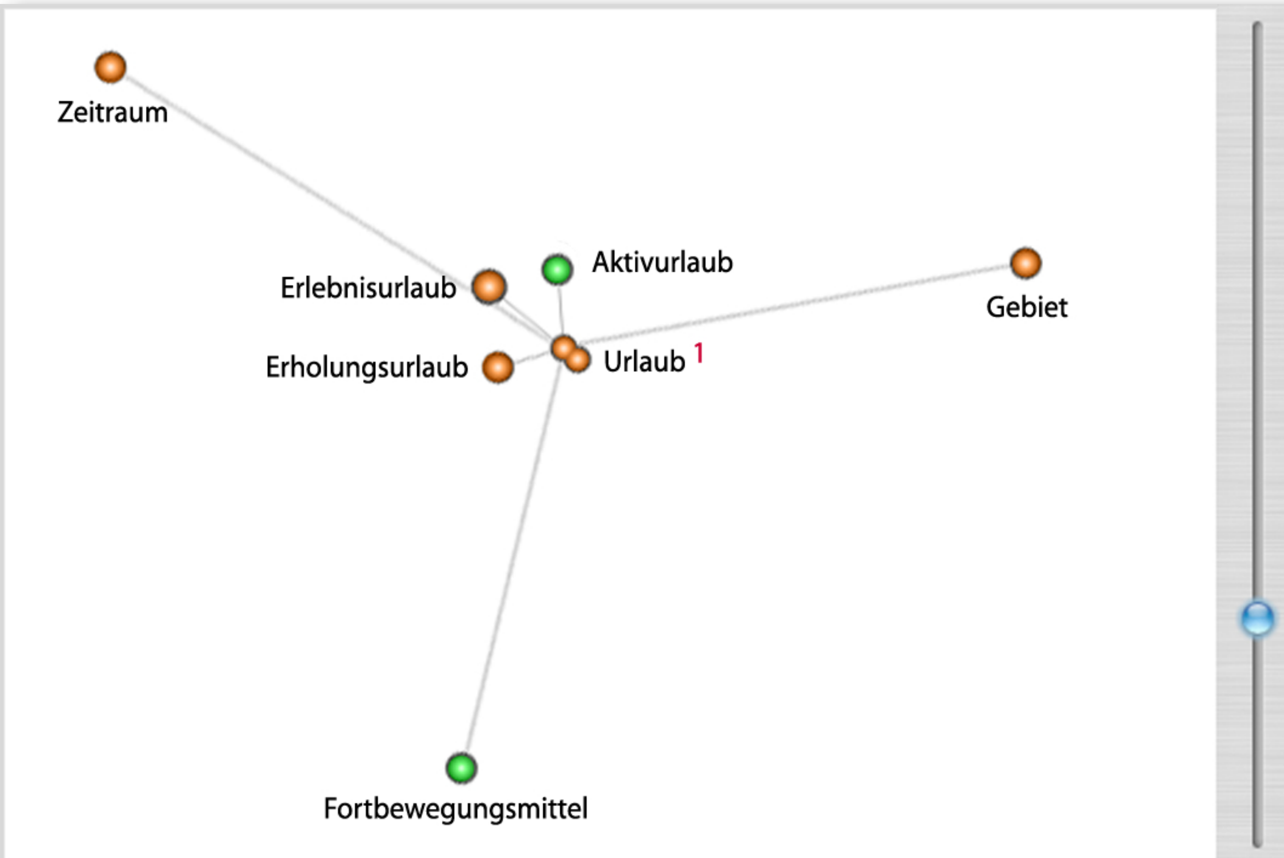
- Focus on a certain entity, visualization the entitiy and its context
- Small world graph visualizations of two ontologies in the tourism domain: the focus of the graph is on the entitiy '`Urlaub`' showing all related concepts for both ontologies
- Labeling is activated
- This view includes all sub-entities (transitive relation) and directly related entities (non-transitive relation), supplemented with all relations and entities among them within a beforehand defined number of hops (relations)
- The nodes are not clustered meaning each node of the graph represents one entity

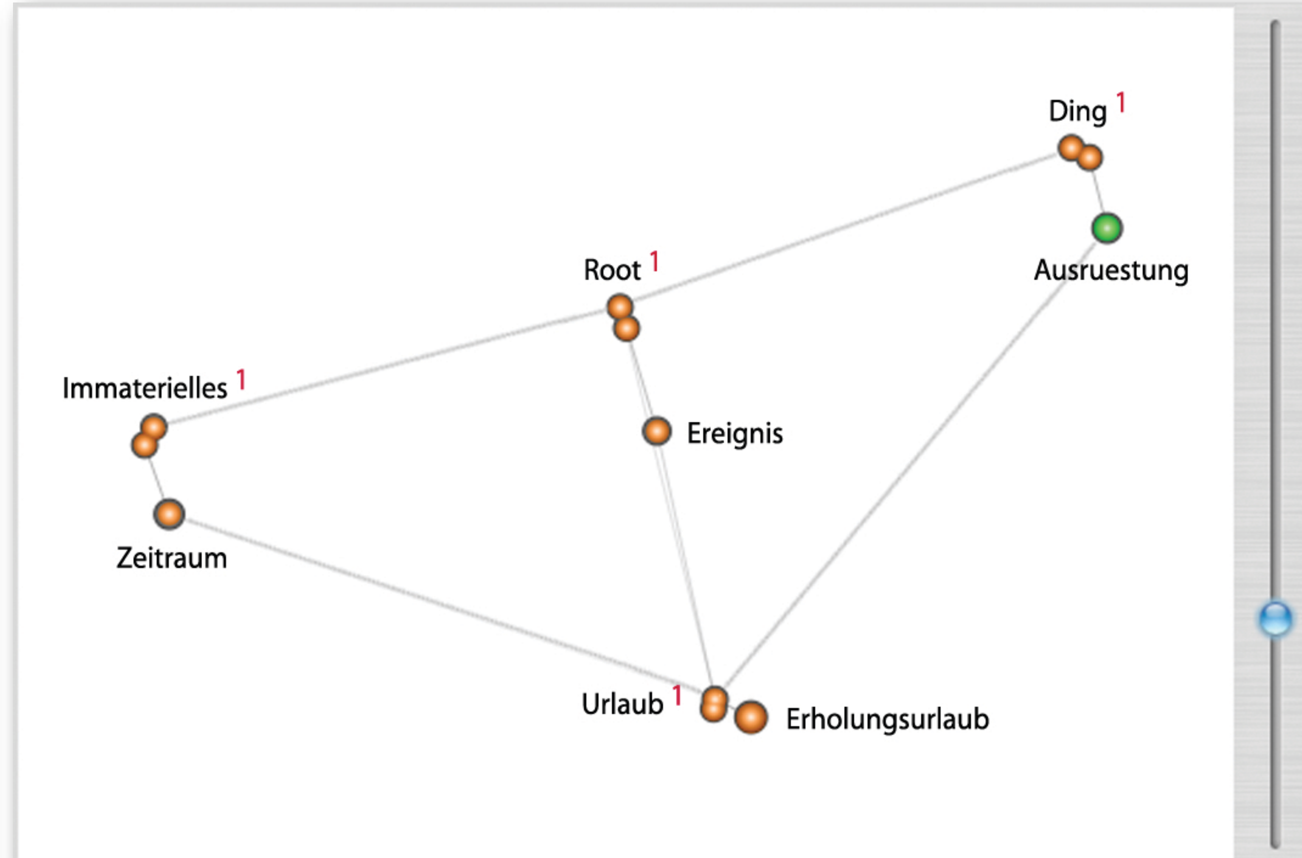




- The edges represent three different types of relations
  In tourismA the depicted relations are:
  `IsA`, `hatReisedauer`, `hatZiel`, `hatReisemittel`
  In tourismB `IsA`, `hatEineDauer`, `manBenoetigtAusruestung`, `hatEinZiel`
- The IsA paths are shorter than the other because we gave these edges a higher weight
- To distinguish different types of relations such as functional, transitive, or non-transitive we apply different weights, which can be modified by the user according to the exploration needs

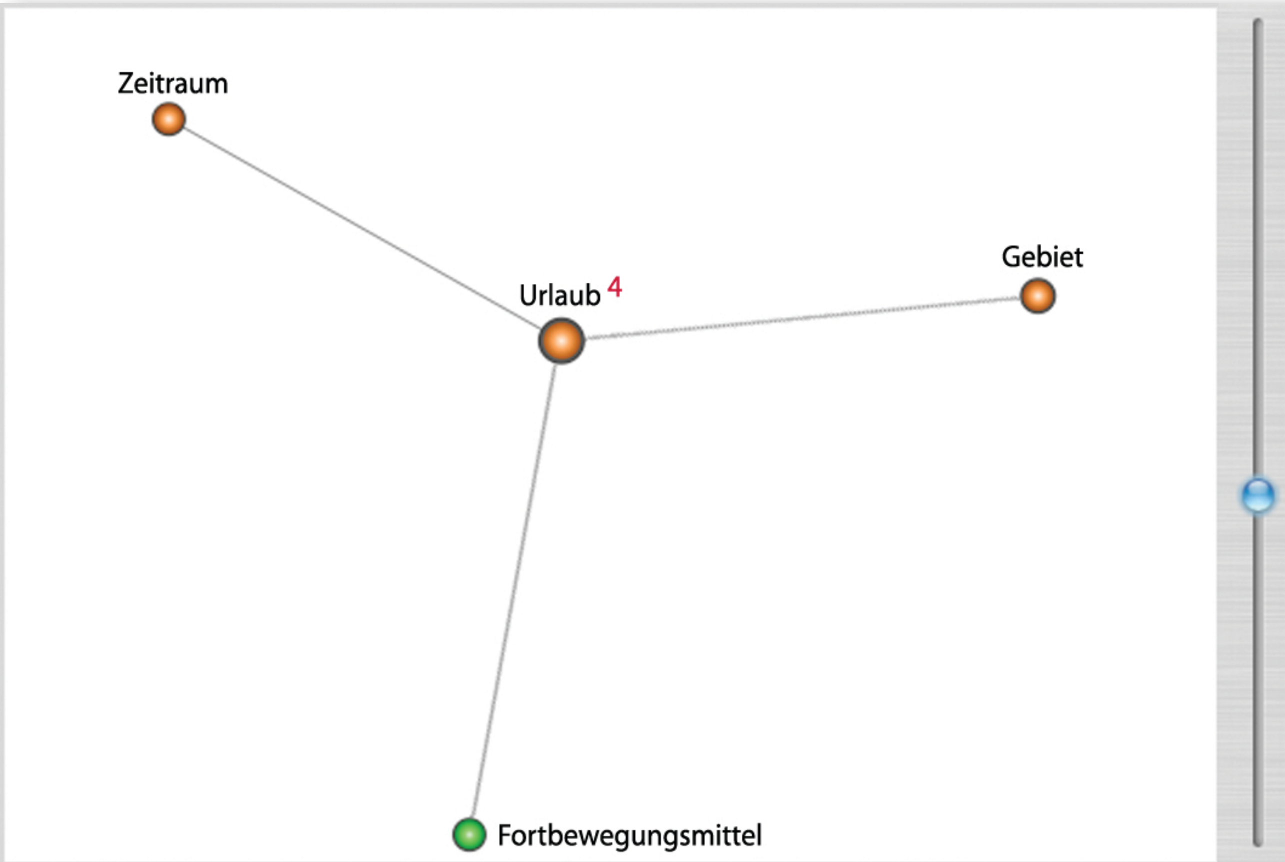
Partly Clustered Subgraphs of Tourism Ontology

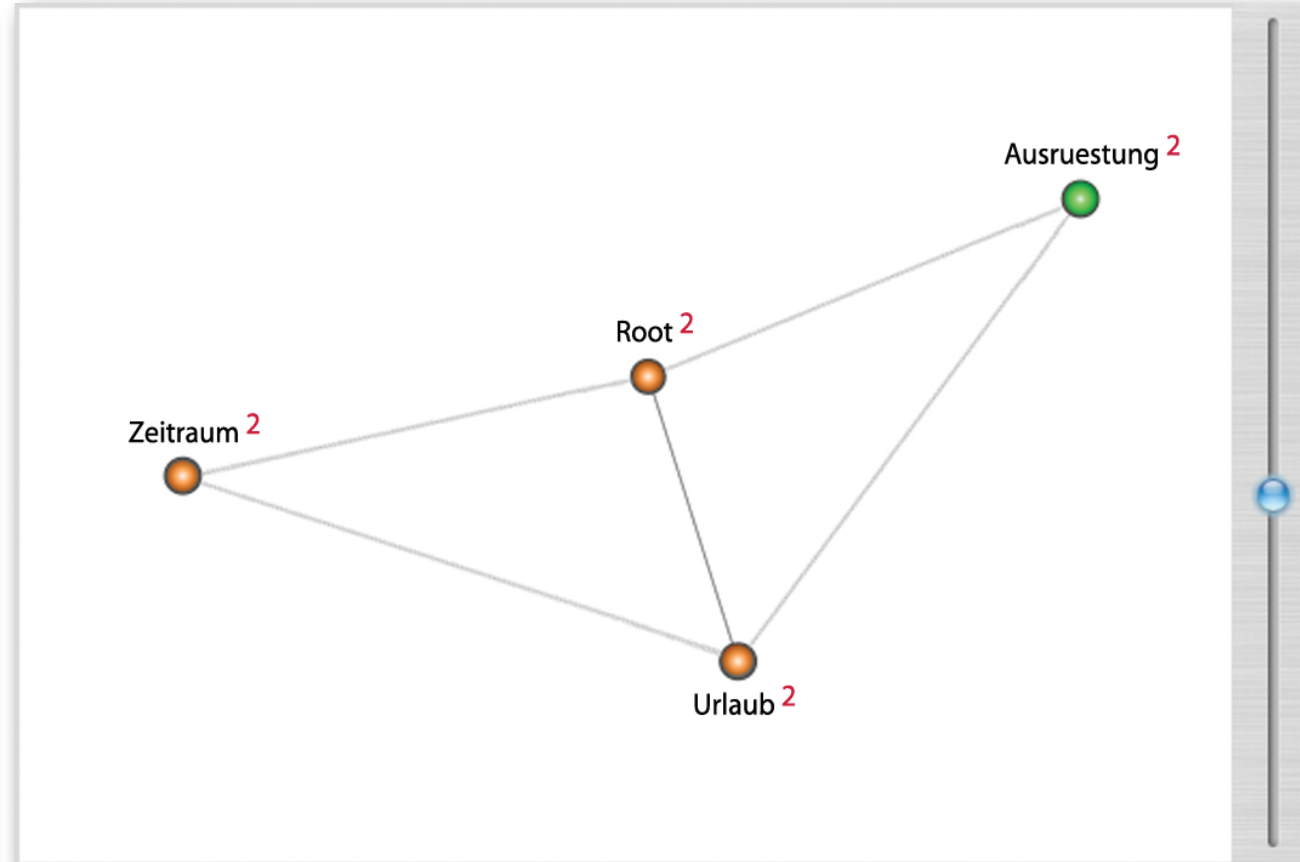




- By moving the cluster sliders next to the graph the user can zoom in or out
- The number of aggregated entities is shown next to the label
- This example shows the clustering along the '`IsA`' relations - transitive relations are clustered first

Partly Clustered Subgraphs of Tourism Ontology





- Clustering emphasizes the structure of the ontology
- An iterative process of zooming in and out allows to explore the ontology on different levels of detail.
- Here clustering fades out the '`IsA`' relationships among the entities focusing on the non-transitive relations of the central entity '`Urlaub`'
- In tourismA '`Urlaub`' is related to '`Gebiet`', '`Fortbewegungsmittel`', and '`Zeitraum`'
- In tourismB the related entities are: '`Ausruestung`', ' `Root` ', and ' `Zeitraum`'

Many strengths:

- Location:
  Where do most of the mappings between ontologies occur?
- Impact:
  Do the mapping choices directly or indirectly affect parts of the ontology the user is concerned about?
- Type:
  What kinds of mappings occur between the ontologies?
- Reason:
  Why do this mappings exist?

... open issues ...

- Show multiple associations
  (emphasized the 'relatedness' of ontologies)
- Pre-define weights of edges for groups of properties
  (e.g., transitive, symmetric, functional, inverse functional)
- Consider confidence value or correct value
- Use methods of graph analysis
  to support the analysis of the alignments

- Include focus+context techniques
  (e.g., distortion or SDOF)
- Labeling / Coloring of edges
- Stronger integration of AlViz and the alignment algorithm: re-calculate alignments?
- Detailed user testing

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... Silvia Miksch

for making nice slides on hierarchical data visualization available.