Seeing, Hearing, and Touching:
Putting It All Together

Seeing Module

Rapid Vision	Rensink
Visual Encoding	Munzner
Procedural Vision	Rensink
Navigating Visual Space	**Munzner**

Imager Laboratory for Graphics, Visualization and HCI

HCI @UBC
Human Computer Interaction
University of British Columbia

SIGGRAPH2004

Overview

Visual Encoding

- Perceptual Channels
- Visualization Frameworks
- Spatial Layout
- Color

Navigating Visual Space

- External Representation
- Layering
  - Occlusion
  - Highlighting
- Spatial Navigation
  - Zooming
  - Focus+Context

External Representation

reduces load on working memory

- offload cognition

familiar example: multiplication/division

External Representation: multiplication

paper	mental buffer

$$\begin{array}{r} 57 \\ \times\ 48 \\ \hline \end{array}$$

External Representation: multiplication

paper	mental buffer
57 x 48 ----	[7*8=56]

External Representation: multiplication

paper

mental buffer

```
   5
  57
x 48
----

   6
```

[7*8=56]

External Representation: multiplication

paper | mental buffer

```
   5
  57
x 48
----

   6
```

[5*8=40 + 5 = 45]

External Representation: multiplication

paper

mental buffer

```
  57
x 48
----

 456
```

[5*8=40 + 5 = 45]

External Representation: multiplication

paper mental buffer

```
  57
x 48        [7*4=28]
----

 456
```

External Representation: multiplication

paper | mental buffer

```
   2
  57
x 48
----

 456
  8
```

[7*4=28]

External Representation: multiplication

paper

mental buffer

```
  2
 57
x48
----

456
 8
```

[5*4=20 + 2 =22]

External Representation: multiplication

paper mental buffer

```
  57
x 48        [5*4=20 + 2 =22]
----

 456
228
```

External Representation: multiplication

paper mental buffer

```
   57
 x 48
 ----

  456
 228
 ----
    6
```

External Representation: multiplication

paper　　　　　　　　　mental buffer

```
   57
 x 48
 ----

  456
 228_                [8+5 = 13]
 ----
    6
```

External Representation: multiplication

paper | mental buffer

```
  57
x 48
----
 1
 456
228_
----
  36
```

[8+5 = 13]

External Representation: multiplication

paper   mental buffer

```
   57
 x 48
 ----
  1
  456
 228          [4+2+1=7]
 ----
   36
```

External Representation: multiplication

paper mental buffer

```
   57
 x 48
 ----

  456
 258_        [4+2+1=7]
 ----
  736
```

External Representation: multiplication

paper

mental buffer

```
   57
 x 48
 ----
  456
 258
 ----
 2736
```

External Representation

reduces load on working memory

- offload cognition

familiar example: multiplication/division

synthetic example: information visualization

- interactive visual representation of abstract data
- help human perform some task more effectively

External Representation: topic graphs

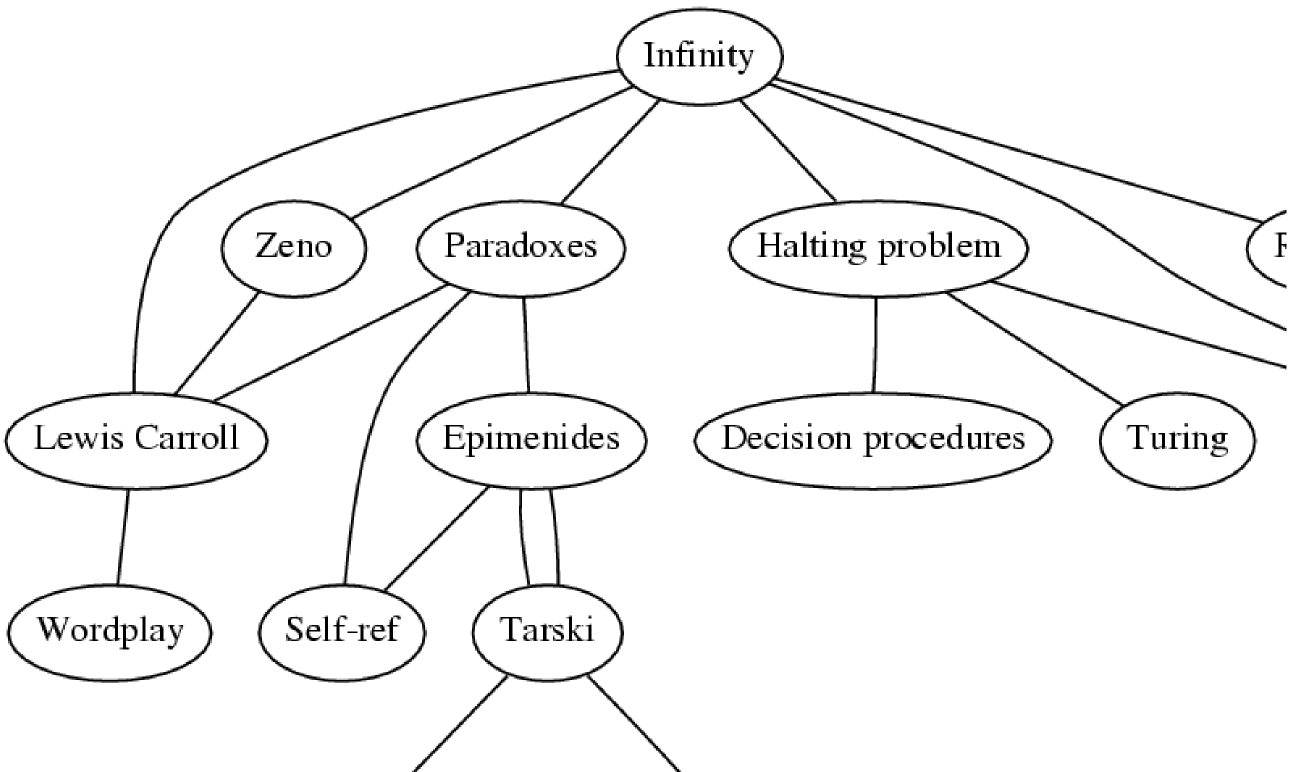
[Godel, Escher, Bach. Hofstadter 1979]

Paradoxes – Lewis Carroll
Turing – Halting problem
Halting problem – Infinity
Paradoxes – Infinity
Infinity – Lewis Carroll
Infinity – Unpredictably long searches
Infinity – Recursion
Infinity – Zeno
Infinity – Paradoxes
Lewis Carroll – Zeno
Lewis Carroll – Wordplay

Halting problem – Decision procedures
BlooP and FlooP – AI
Halting problem – Unpredictably long searches
BlooP and FlooP – Unpredictably long searches
BlooP and FlooP – Recursion
Tarski – Truth vs. provability
Tarski – Epimenides
Tarski – Undecidability
Paradoxes – Self-ref
[…]

External Representation: topic graphs

offload cognition to visual systems
read off answer



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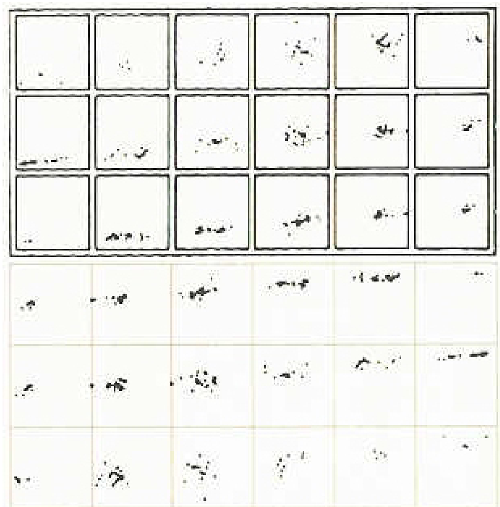
Layering: Cartography

Layering: Backgrounds

want subtler background than foreground



[Tufte, Envisioning Information, Chap 3]

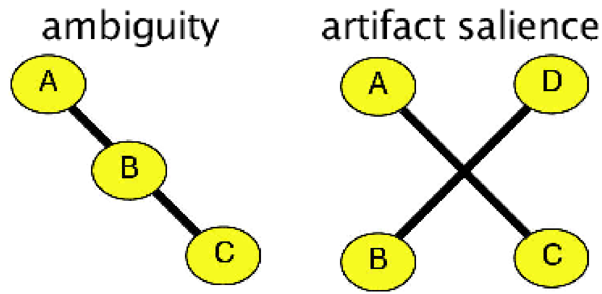
Layering: Graphs

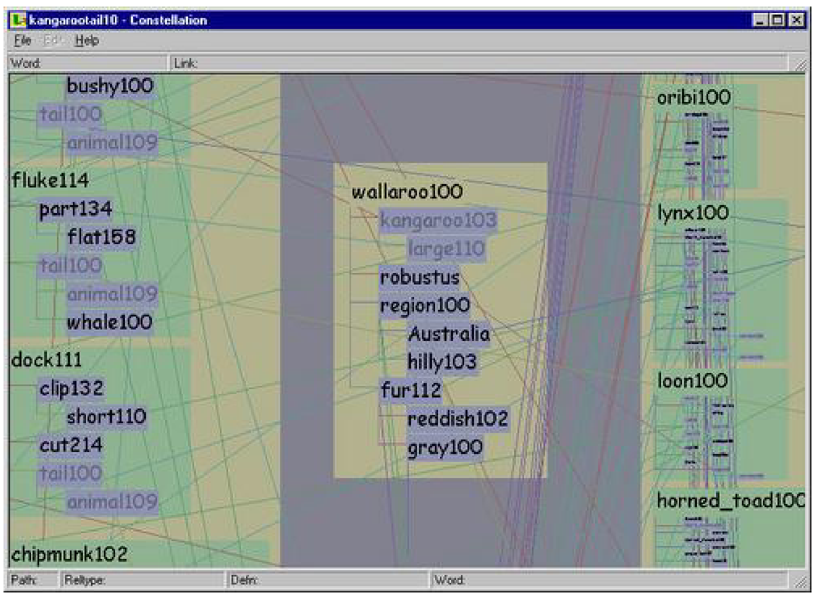
edge crossing problem

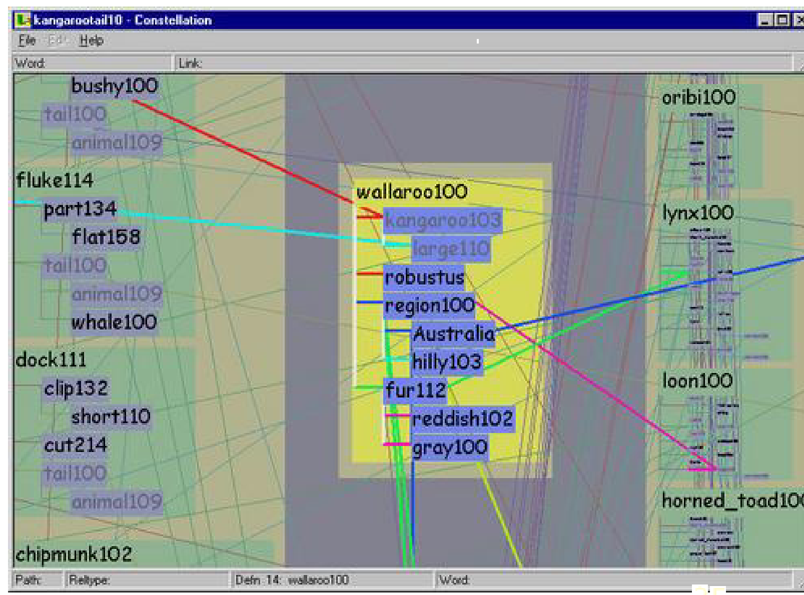
- false attachments

layers to avoid perception

- vs. spatial position





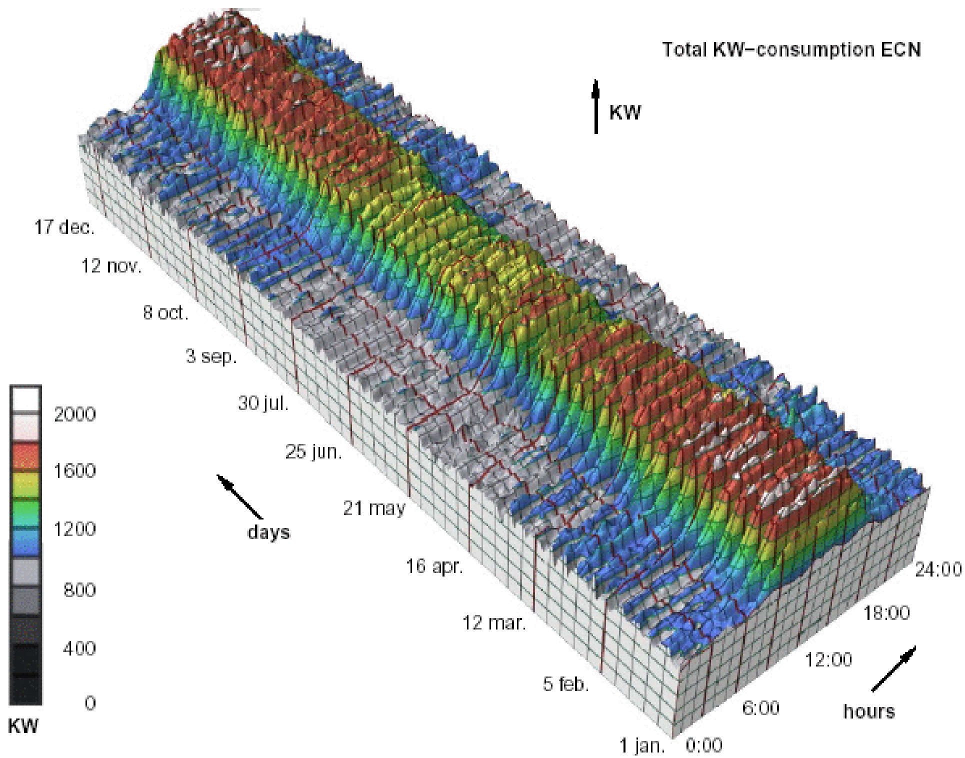


[Munzner et al, Constellation, graphics.stanford.edu/papers/const]

Occlusion: Extrusion into 3D

3D time-series extrusion pretty but not useful

- occlusion hides, perspective makes comparison hard
- daily, weekly patterns hard to find



[van Wijk and van Selow, Cluster and Calendar-based Visualization of Time Series Data. InfoVis99. citeseer.nj.nec.com/vanwijk99cluster.html]

Time-series Data Analysis

van Wijk and van Selow, InfoVis 99

- Cluster and Calendar based Visualization of Time Series Data

data: N pairs of (value, time)

- N large: 50K

tasks

- find standard day patterns
- find how patterns distributed over year, week, season
- find outliers from standard daily patterns
- want overview first, then detail on demand

Hierarchical Clustering

start with all M day patterns

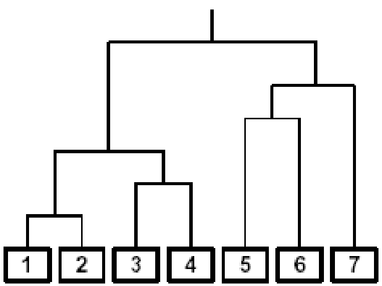
- compute mutual differences, merge most similar
- continue up to 1 root cluster

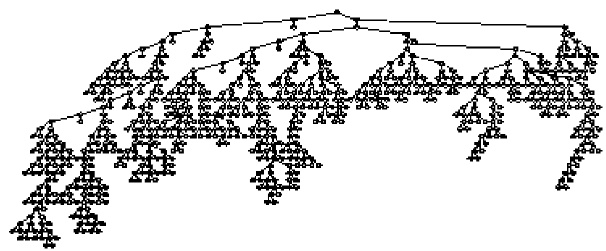
result: binary hierarchy of clusters

- choice of distance metrics

dendrogram display common

- shows structure of hierarchy
- does not solve pattern finding problem!



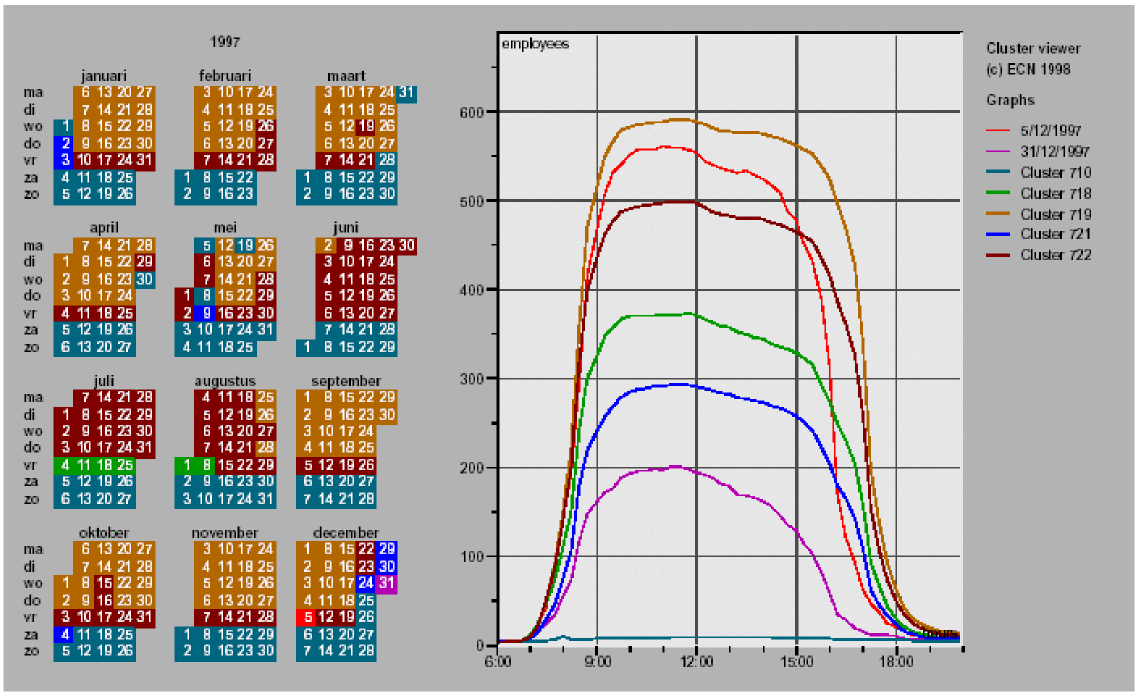


Link Clusters and Calendar

linked 2D calendar+clusters shows patterns

- plot: number of employees vs. time of day

  office hours, fridays/summer, school break, weekend/holidays, post-holiday, santa claus

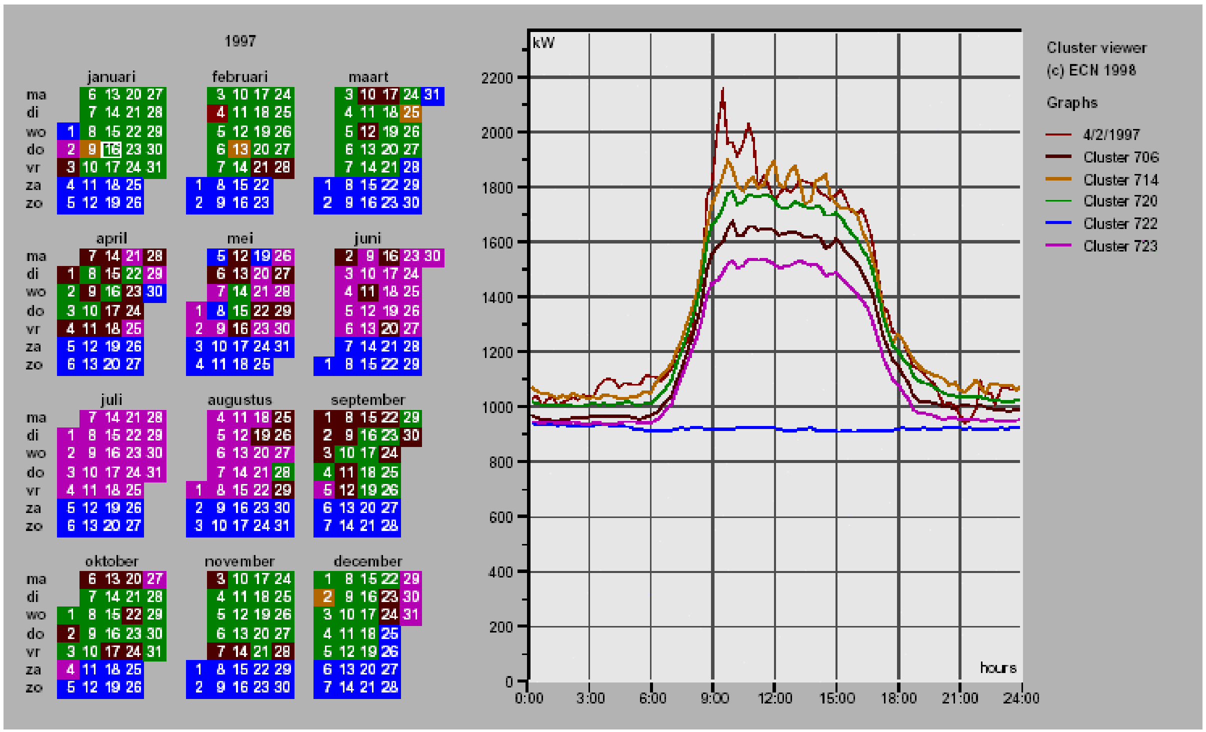


[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, InfoVis99, Figure 4, citeseer.nj.nec.com/vanwijk99cluster.html]

Link Clusters and Calendar

linked 2D calendar+clusters shows patterns

- plot: power consumption vs. time of day



[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, InfoVis99, Figure 5, citeseer.nj.nec.com/vanwijk99cluster.html]

Cluster–Calendar Ideas

task analysis leads away from obvious choices
- 3D extrusion, dendrogram

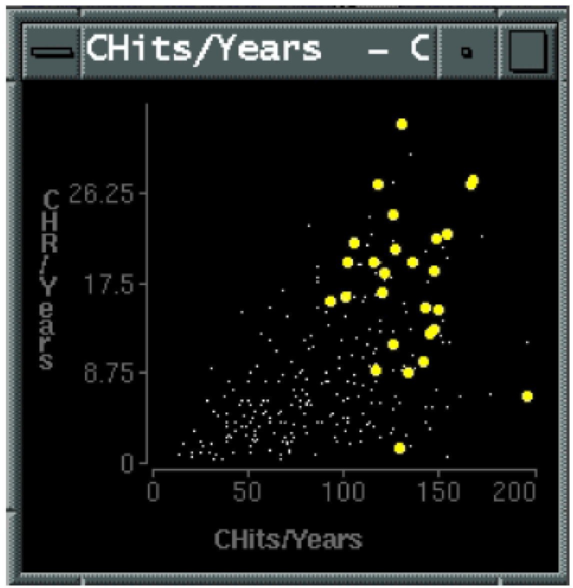
meaningful derived space: clusters

spatial representation of time: calendar
- using space to show time

linked highlighting

Highlighting

- interactively created layer
- direct attention to specific part of scene
- through change of perceptual channel(s)
  - color, size/linewidth, motion



[Visual Exploration of Large Structured Databases, Graham J. Wills, in New Techniques and Trends in Statistics, pp 237-246, IOS Press 1995.]

Linked Highlighting

selection in one view changes other views too
aka brushing, coordinated views

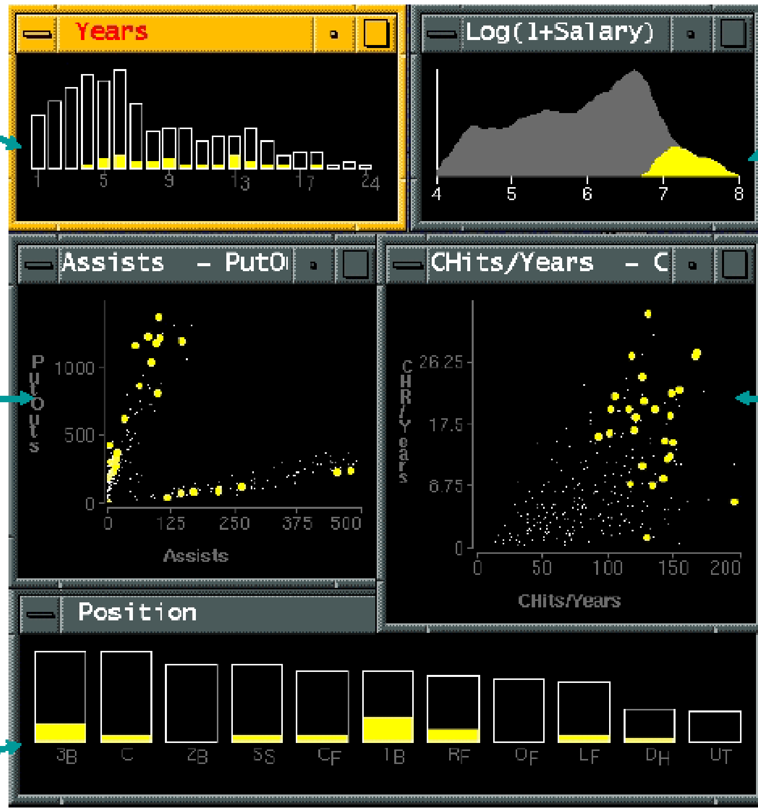
how long in majors

select high salaries

avg assists vs avg putouts (fielding ability)

avg career HRs vs avg career hits (batting ability)

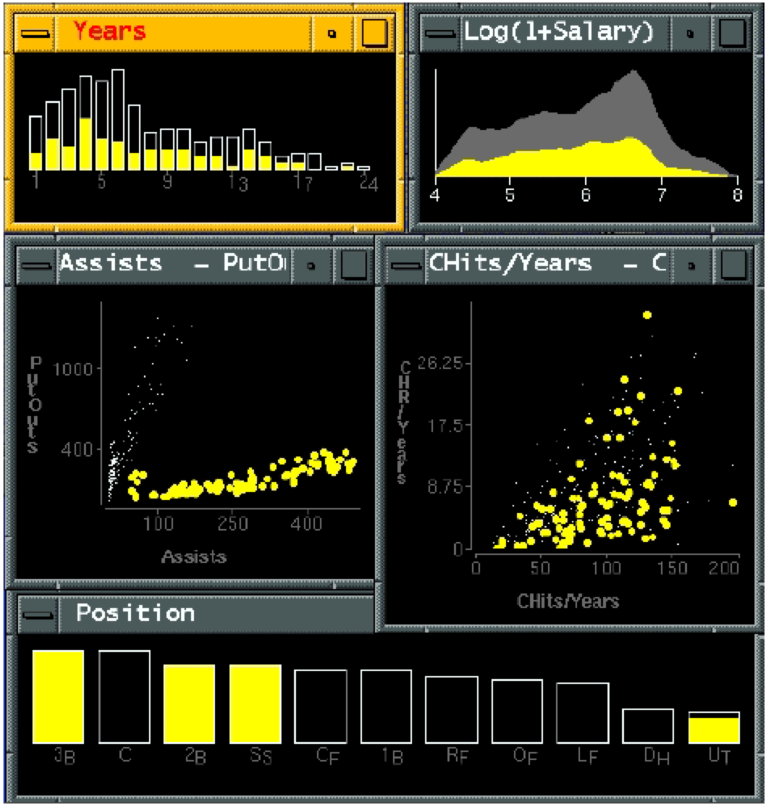
distribution of positions played



[Visual Exploration of Large Structured Databases, Graham J. Wills, 1995.]

Linked Highlighting

Exploratory Data Visualizer

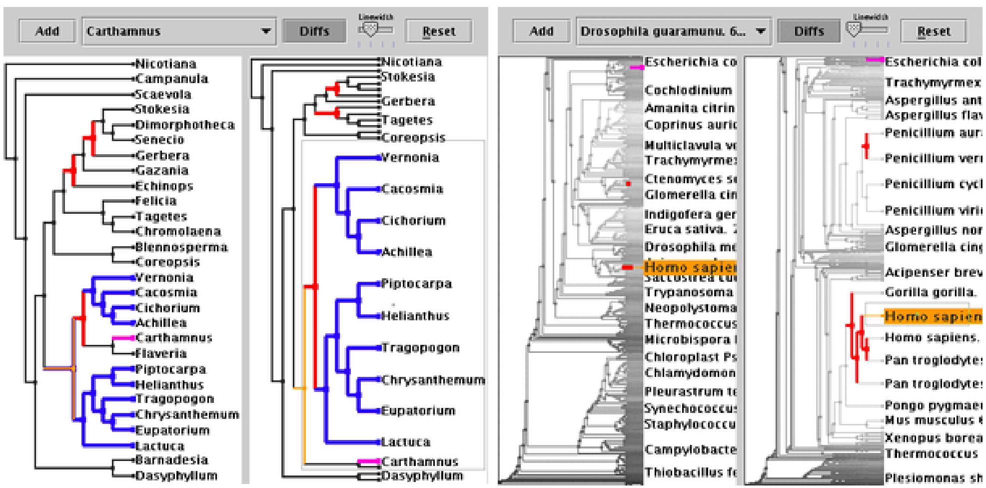


[Visual Exploration of Large Structured Databases, Graham J. Wills, in New Techniques and Trends in Statistics, pp 237-246, IOS Press 1995.]

Guaranteed Visibility

- keeping highlighted marks visible at all times
- potentially difficult with big datasets
  - out of viewport, occlusion, subpixel size
- linked highlighting of best corresponding item

[demo]



[TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility. Munzner et al. SIGGRAPH 2003. http://www.cs.ubc.ca/~tmm/papers/tj]

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Spatial Navigation

real-world navigation only partially understood

- compared to low-level perception
- 3D vs. 2D: we don't fly, we walk

spatial memory / environmental cognition

- city: landmark/path/whole

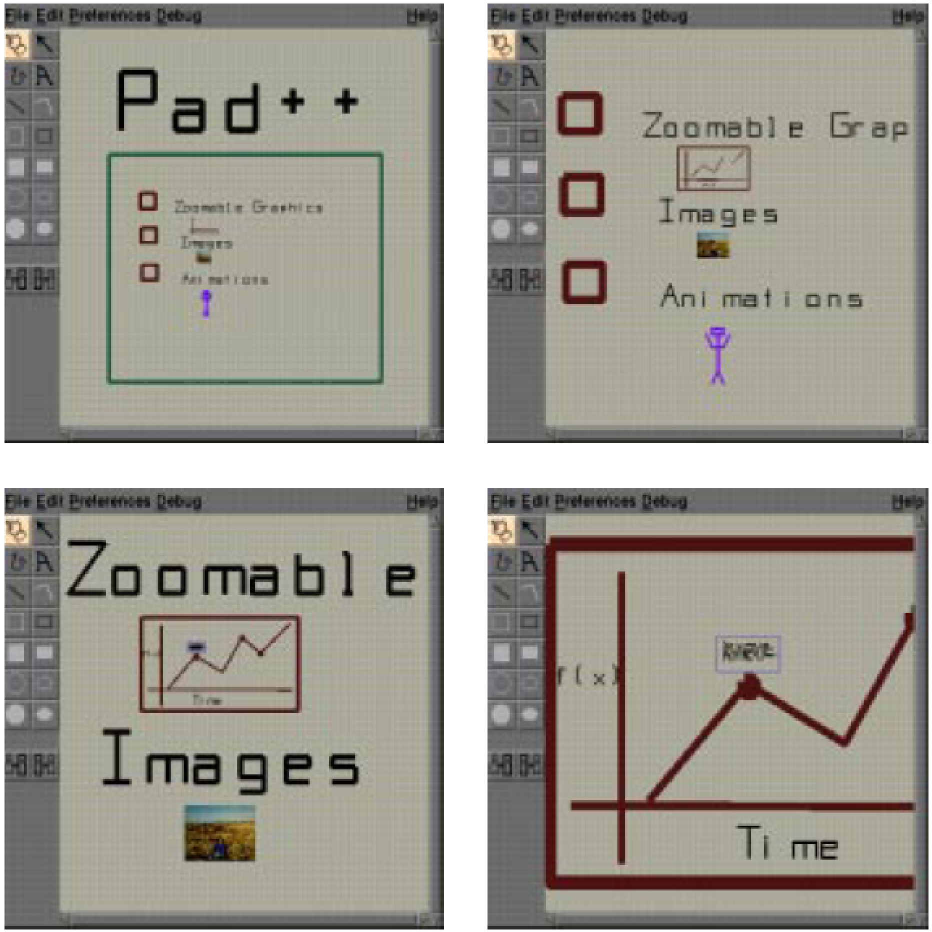
[The Image of the City, Kevin Lynch, MIT Press 1960]

motion beyond rigid rotate/translate/zoom

- multiscale navigation
- speed-dependent automatic zooming
- Focus+Context

Multiscale Zoomable User Interfaces

Pad++



Space-Scale Diagrams

reasoning about navigation and trajectories

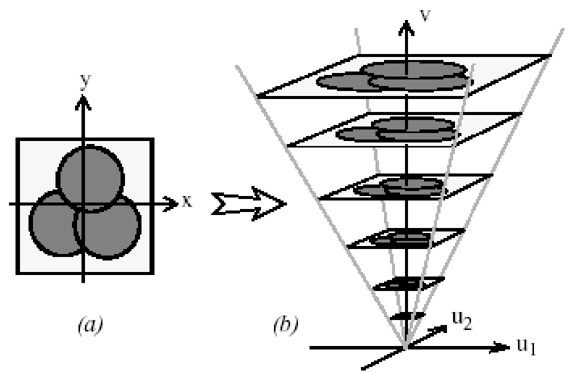
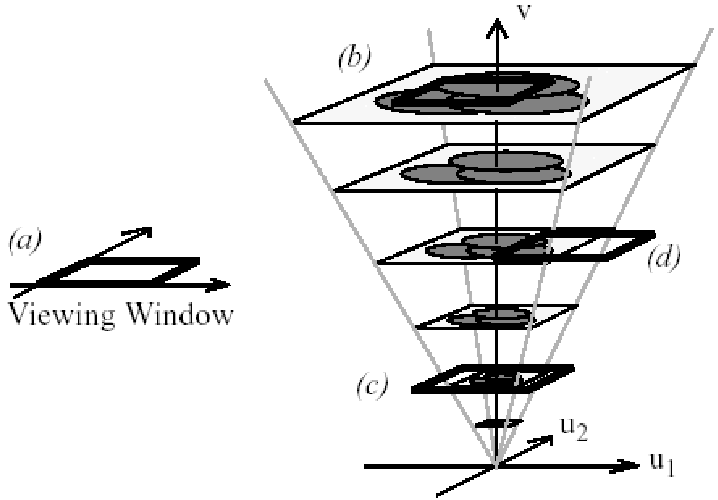


Figure 1. *The basic construction of a Space-Scale diagram from a 2D picture.*

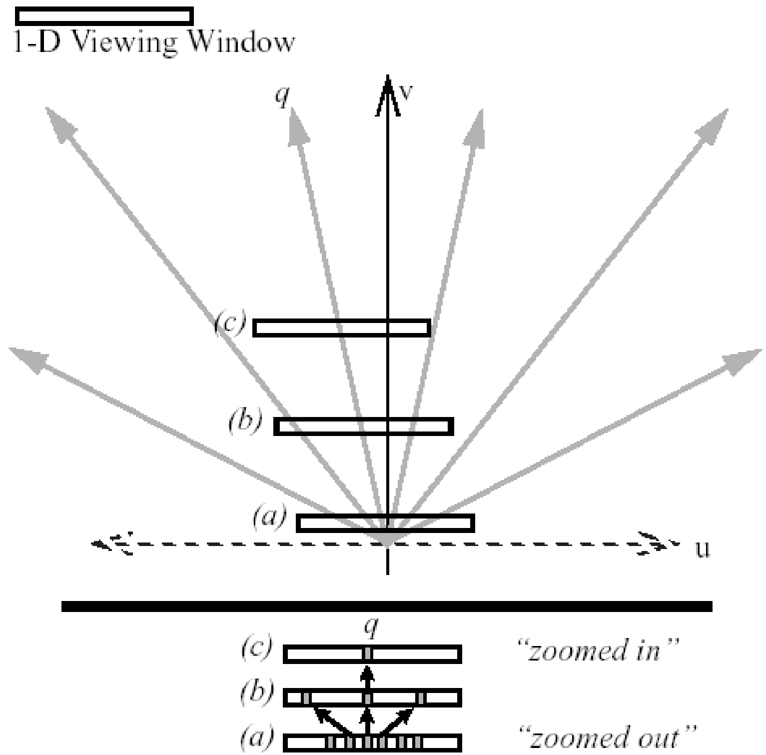
[Space-Scale Diagrams: Understanding Multiscale Interfaces
George Furnas and Ben Bederson, Proc SIGCHI '95.
www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

Viewing Window



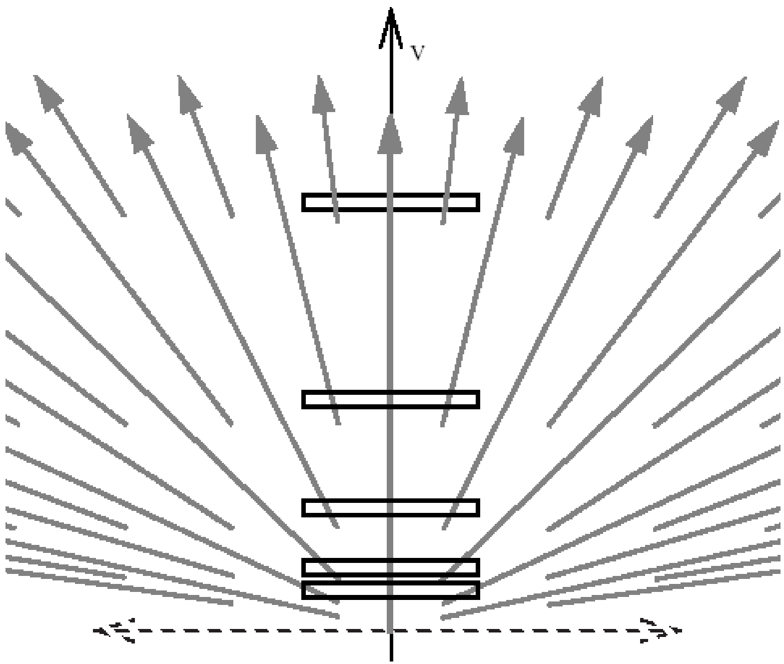
[www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

1D Version



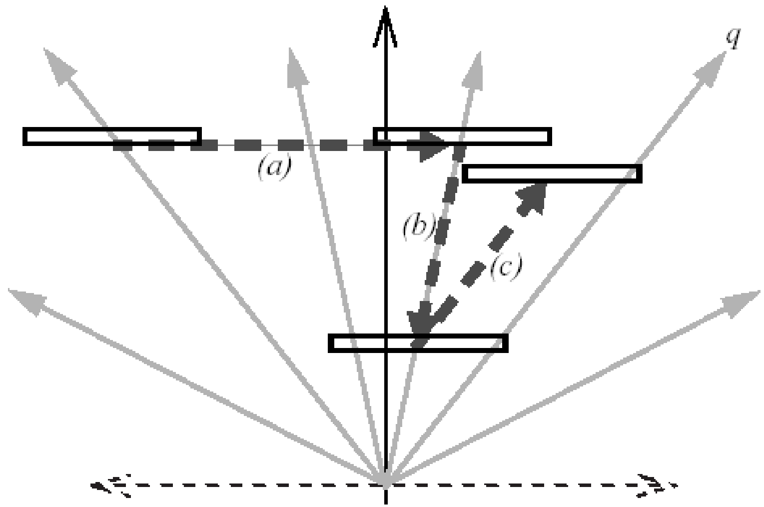
[www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

Multiscale Display



[www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

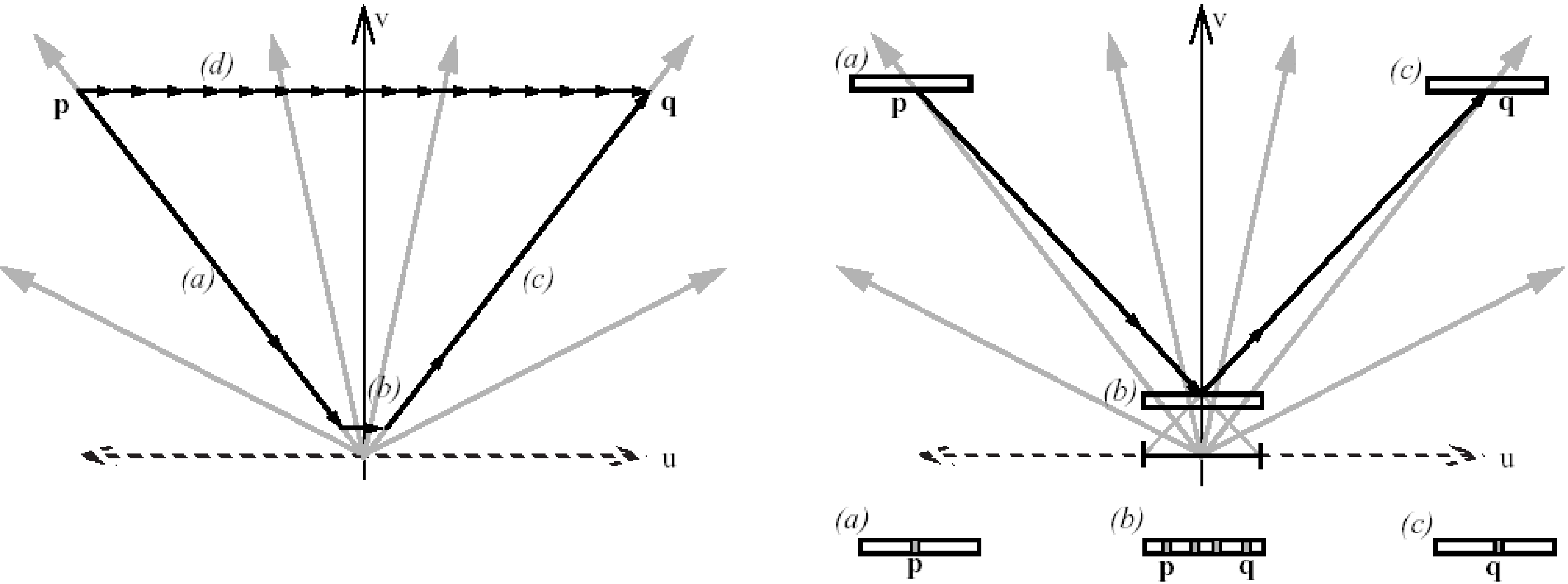
Pan-Zoom Trajectories



[www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

Shortest Path

anisotropic cost: zooming vs. panning



[www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

Speed-Dependent Automatic Zooming

automatic zoom calculated from pan distance

[video]

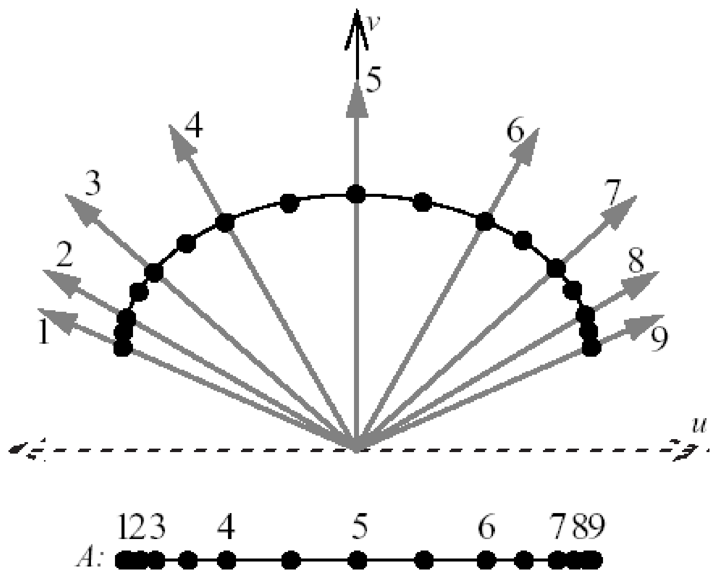
[www-ui.is.s.u-tokyo.ac.jp/~takeo/video/autozoom.mov]

try out demo yourself:

[www-ui.is.s.u-tokyo.ac.jp/~takeo/java/autozoom/autozoom.htm]

[Speed-Dependent Automatic Zooming for Browsing Large Documents
Takeo Igarashi and Ken Hinckley, Proc. UIST'00, pp. 139-148.
www-ui.is.s.u-tokyo.ac.jp/~takeo/papers/uist2000.pdf]

Fisheye View



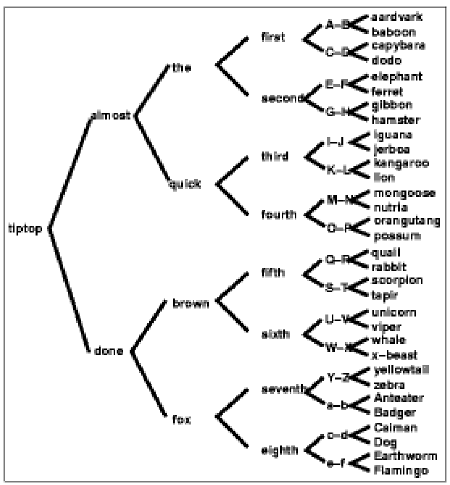
example of Focus+Context

[www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

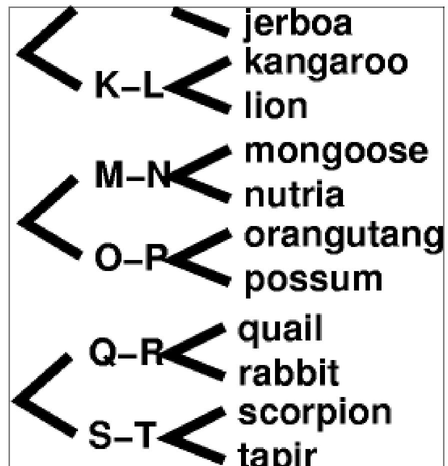
Focus+Context: avoiding disorientation

problem
- maintain user orientation when showing detail
- hard for big datasets

graph example
- exponential in depth: node count, space needed
- global overview: can't read labels
- detail view: can't see context



global overview

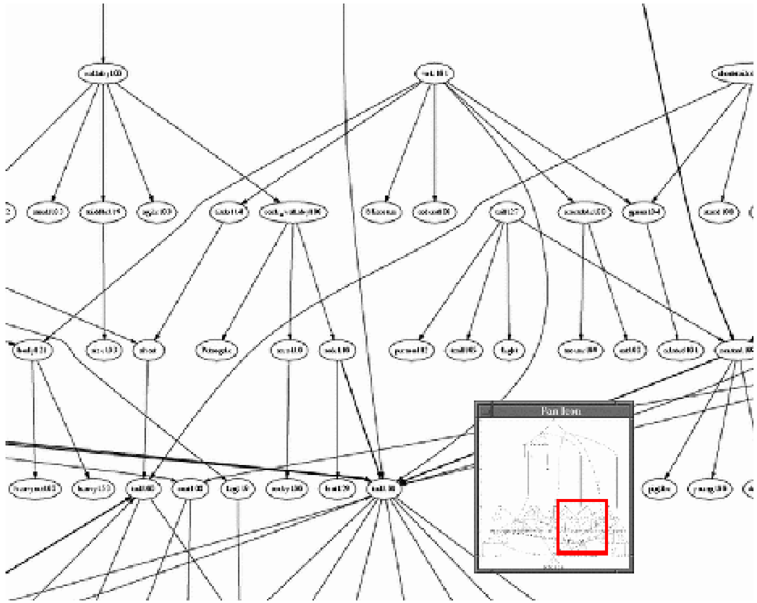


local detail

Overview and Detail

two windows: add linked overview

- cognitive load to correlate



solution

- merge overview and detail into combined view

Single Combined View: Many Names

distortion-oriented presentation techniques
- [Leung94]

elastic presentation spaces
- [Carpendale01]

fisheye views
- [Furnas86,Sarkar94]

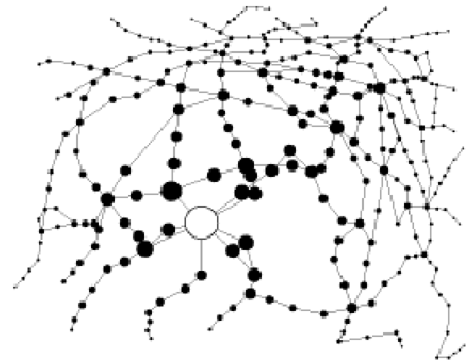
focus+context
- [Rao94]

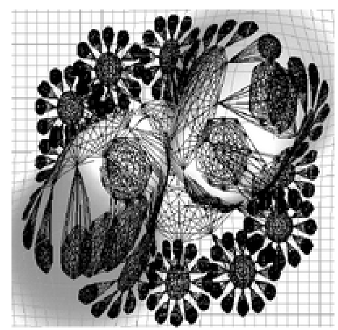
hyperbolic views
- [Rao95, Munzner97]

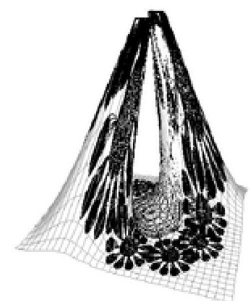
nonlinear distortion
- [Keahey97]

pliable surfaces
- [Carpendale95]

stretchable rubber sheet
- [Sarkar93, Robertson93, Munzner03]



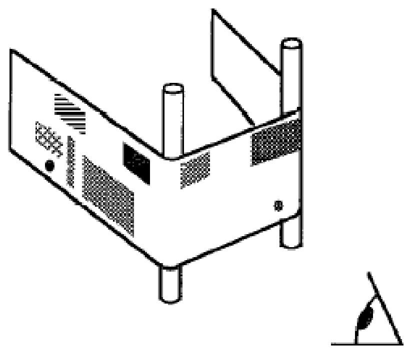




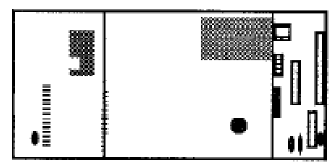
Focus+Context Intuition

stretch surface: move part closer to eye

- Bifocal Display, Perspective Wall



(a)

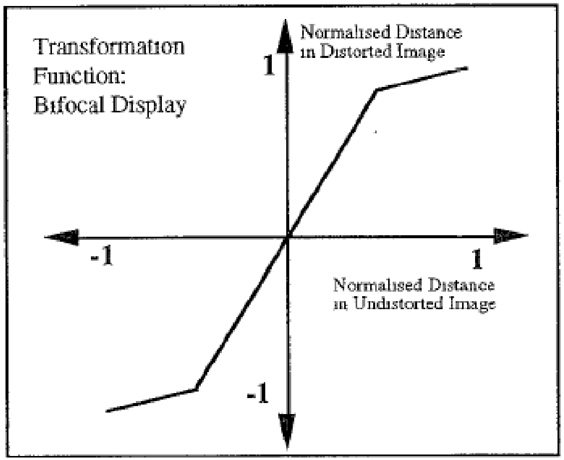


(b)

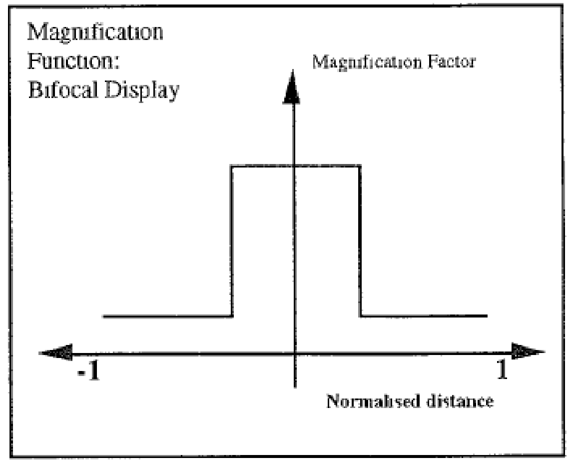
[A Review and Taxonomy of Distortion-Oriented Presentation Techniques. Leung and Apperley, www.ai.mit.edu/people/jimmylin/papers/Leung94.pdf]

Bifocal

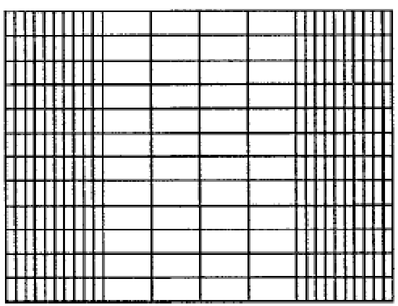
transformation



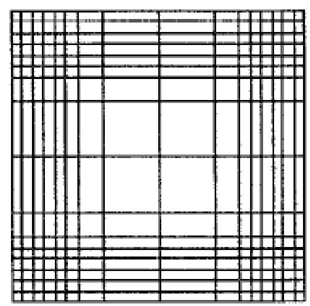
magnification



1D



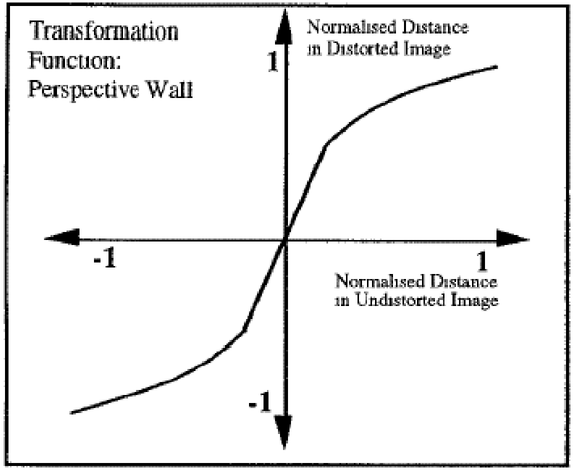
2D



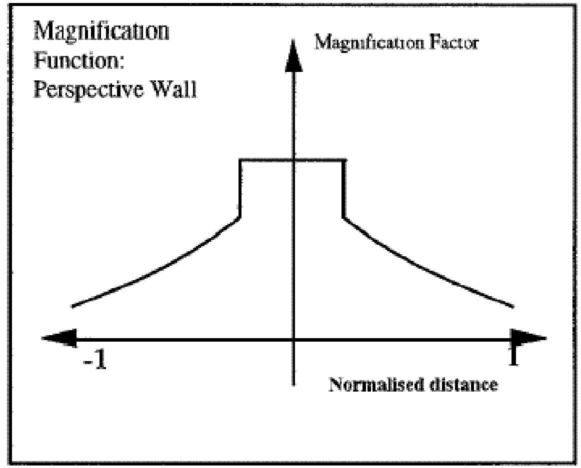
[A Review and Taxonomy of Distortion-Oriented Presentation Techniques]

Perspective Wall

transformation



magnification



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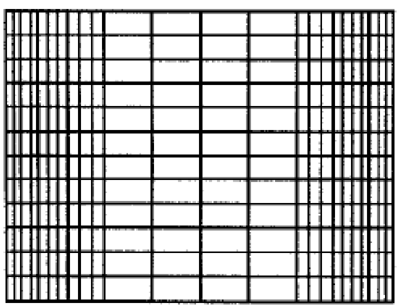
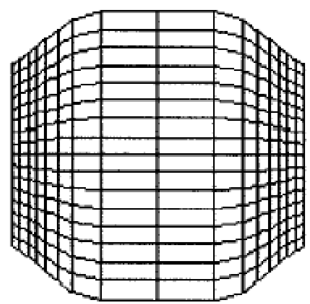


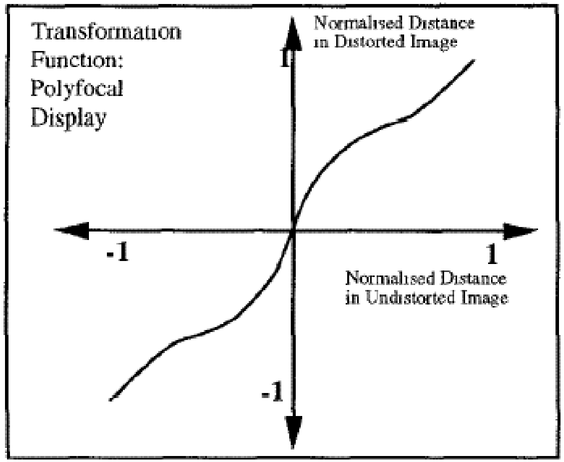
2D



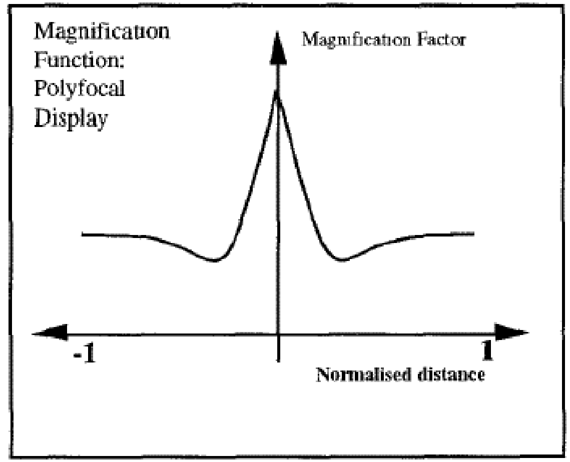
[A Review and Taxonomy of Distortion-Oriented Presentation Techniques]

Polyfocal: Continuous Mag

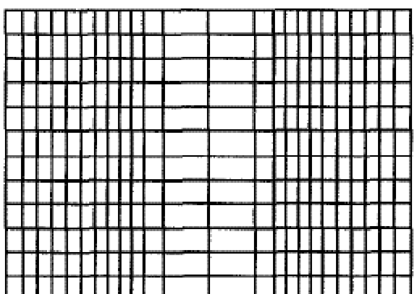
transformation



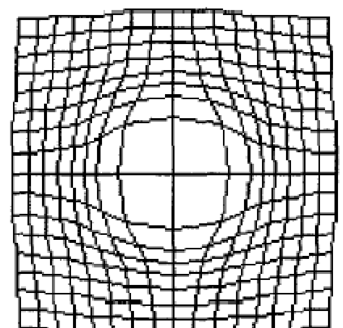
magnification



1D



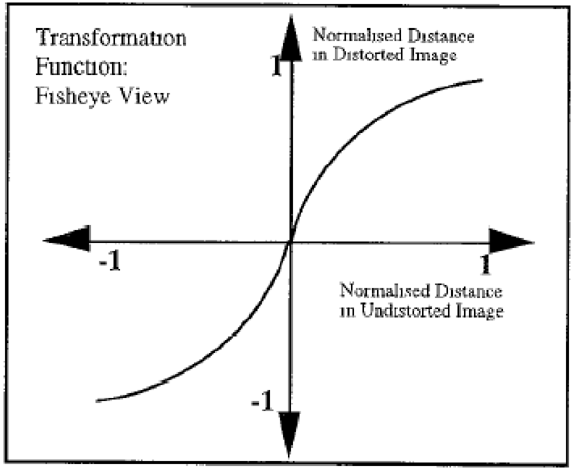
2D

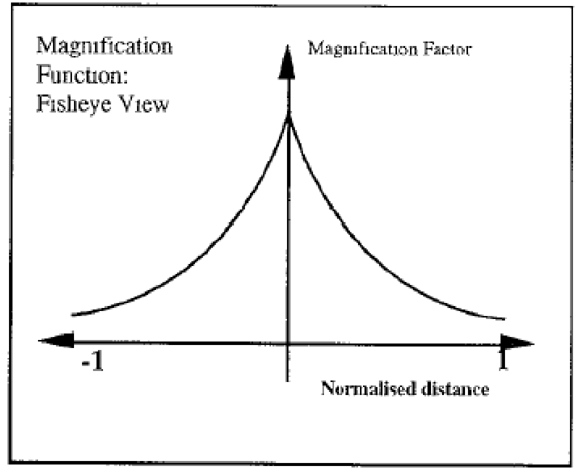


[A Review and Taxonomy of Distortion-Oriented Presentation Techniques]

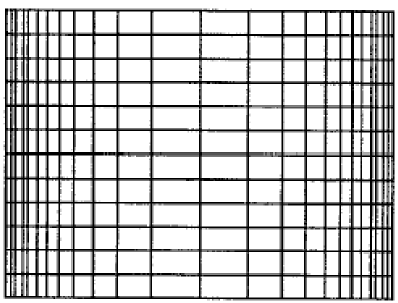
Fisheye Views: Continuous Mag

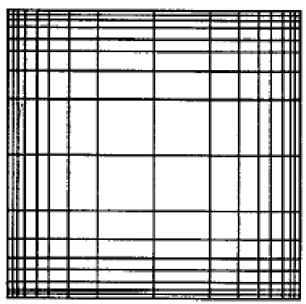
transformation magnification

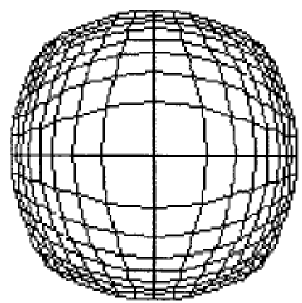


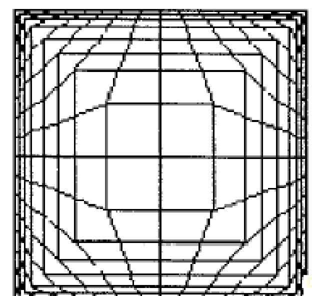


1D 2D rect polar norm polar





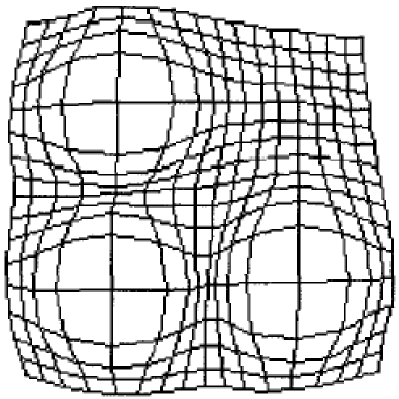




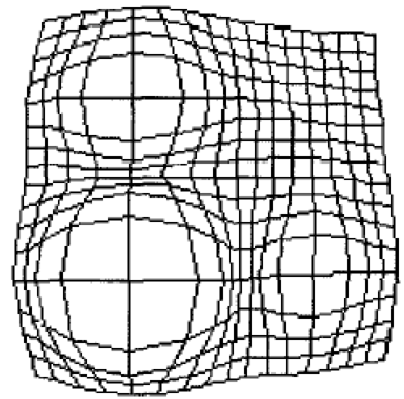
[A Review and Taxonomy of Distortion-Oriented Presentation Techniques]

Multiple Foci

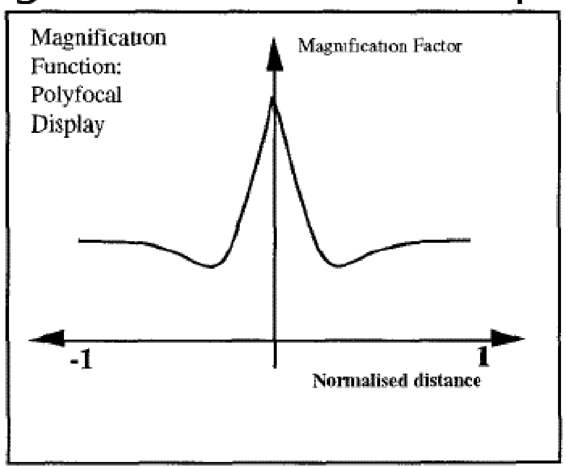
same params



diff params



polyfocal magnification function dips allow this



Nonlinear Magnification Functions

transformation
- distortion

magnification
- derivative of transformation

directionality
- easy: compute magnification given transformation
  derivative
- hard: compute transformation given magnification
  integration

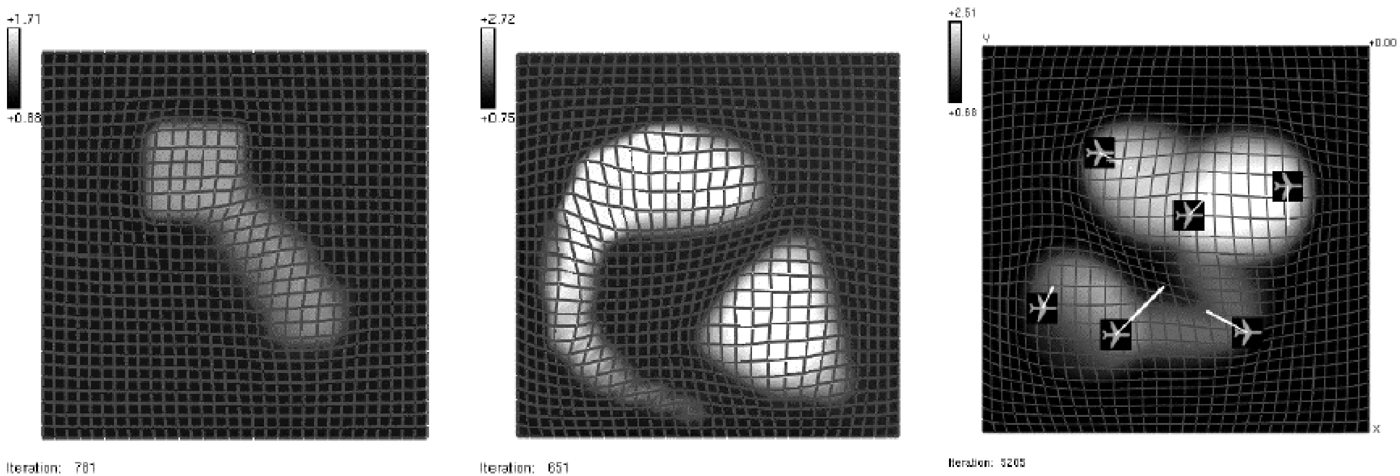
new mathematical framework
- approximate integration, iterative refinement
- minimize "error mesh"

[Nonlinear Magnification Fields. Alan Keahey, Proc InfoVis 1997]

Nonlinear Magnification Expressiveness

magnification is more intuitive control

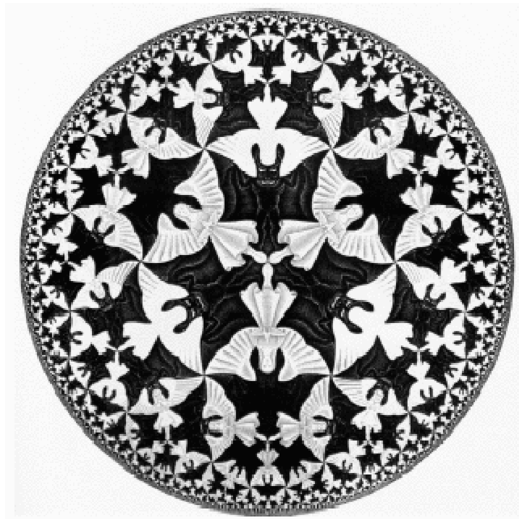
- allow expressiveness, data-driven expansion

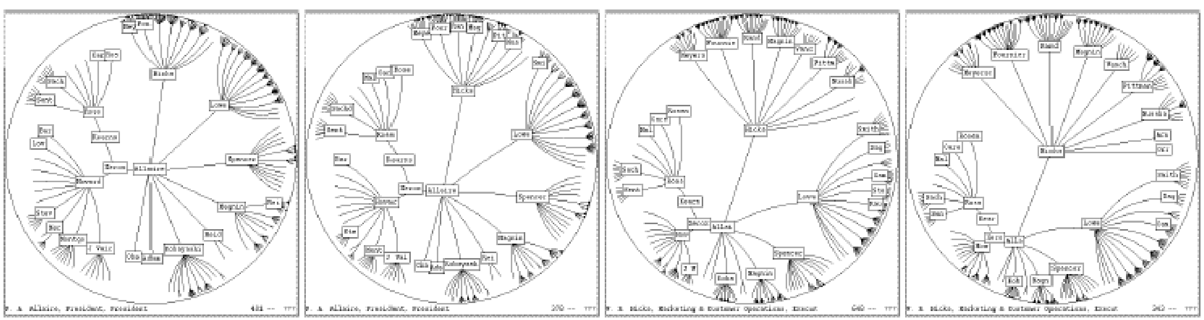


[Nonlinear Magnification Fields. Alan Keahey, Proc InfoVis 1997
ftp://ftp.cs.indiana.edu/pub/tkeahey/papers/infovis.97.pdf]

2D Hyperbolic Trees

fisheye effect from hyperbolic geometry





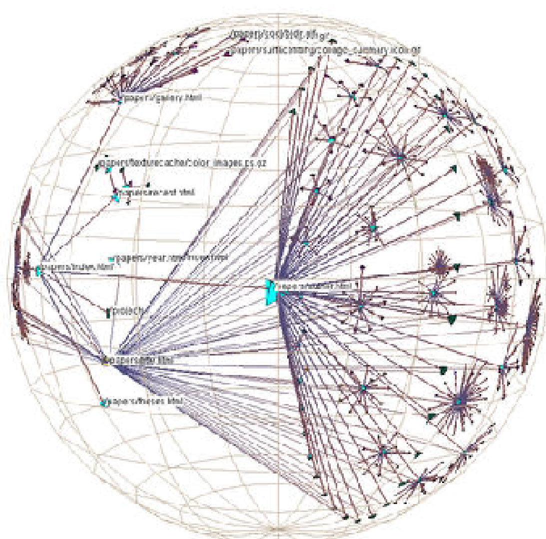
[The Hyperbolic Browser: A Focus + Context Technique for Visualizing Large Hierarchies. John Lamping and Ramana Rao. Proc SIGCHI'95.]

3D Hyperbolic Graphs: H3

3D hyperbolic geometry, tree as backbone

[video]

[graphics.stanford.edu/videos/h3]

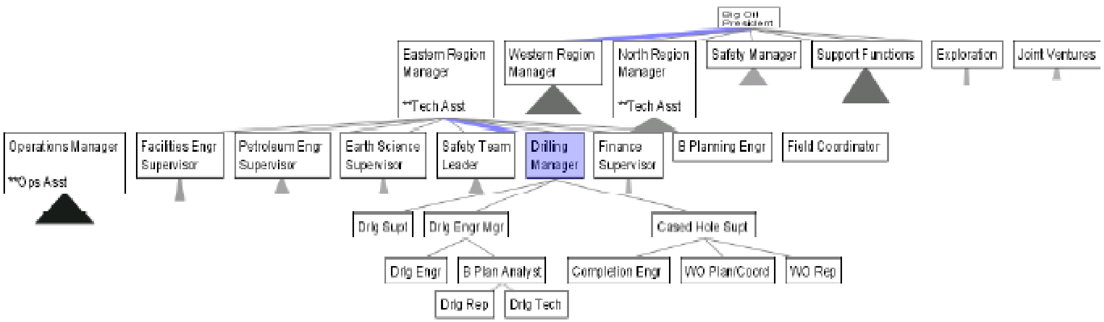


[H3: Laying Out Large Directed Graphs in 3D Hyperbolic Space.
Tamara Munzner, Proc InfoVis 97. http://graphics.stanford.edu/papers/h3]

SpaceTree

focus+context tree [demo]

- interactively expand/contract, not stretching space



[SpaceTree. Catherine Plaisant, Jesse Grosjean and Ben B. Bederson. Proc. InfoVis 2002
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More Reading: Layering, Highlighting

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Interactive Visualization of Large Graphs and Networks
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Tamara Munzner et al, SIGGRAPH 2003.
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More Reading: Navigation, Zooming

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Jock Mackinlay, Stuart Card, and George Robertson.
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George Furnas and Ben Bederson, Proc SIGCHI '95.
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Speed-Dependent Automatic Zooming for Browsing Large Documents
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http://www-ui.is.s.u-tokyo.ac.jp/~takeo/papers/uist2000.pdf

Smooth and Efficient Zooming and Panning.
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http://www.win.tue.nl/~vanwijk/zoompan.pdf

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Nonlinear Magnification Fields. Alan Keahey, Proc InfoVis 1997 ftp://ftp.cs.indiana.edu/pub/tkeahey/papers/infovis.97.pdf

The Hyperbolic Browser: A Focus + Context Technique for Visualizing Large Hierarchies. John Lamping and Ramana Rao, Proc SIGCHI '95. http://citeseer.nj.nec.com/lamping95focuscontext.html

H3: Laying Out Large Directed Graphs in 3D Hyperbolic Space. Tamara Munzner, Proc InfoVis 97. http://graphics.stanford.edu/papers/h3

SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Catherine Plaisant, Jesse Grosjean, and Ben B. Bederson. Proc. InfoVis 2002. ftp://ftp.cs.umd.edu/pub/hcil/Reports-Abstracts-Bibliography/2002-05html/2002-05.pdf

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Manojit Sarkar, Scott S. Snibbe, Oren J. Tversky and Steven P. Reiss.
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