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
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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

57
x 48

External Representation: multiplication

paper mental buffer

57
x 48 [7*8=56]

External Representation: multiplication

paper mental buffer

5
57
x 48 [7*8=56]

6

External Representation: multiplication

paper mental buffer

```
  5
 57
x48
```

[5*8=40 + 5 = 45]

```
 6
```


External Representation: multiplication

paper mental buffer

```
 57
x48
```

[5*8=40 + 5 = 45]

```
456
```


External Representation: multiplication

paper mental buffer

```
 57
x48
```

[7*4=28]

```
456
```


External Representation: multiplication

paper mental buffer

```
  2
 57
x48
```

[7*4=28]

```
456
 8
```


External Representation: multiplication

paper mental buffer

```
  2
 57
x48
```

[5*4=20 + 2 =22]

```
456
 8
```


External Representation: multiplication

paper mental buffer

```
 57
x48
```

[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_          [8+5 = 13]
____
  36
```


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

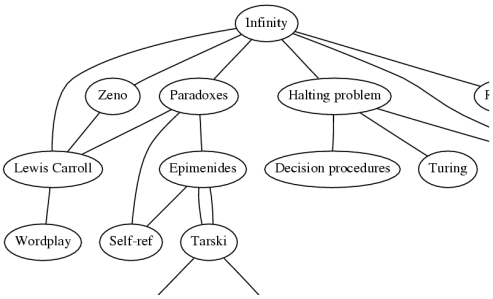
External Representation: topic graphs

[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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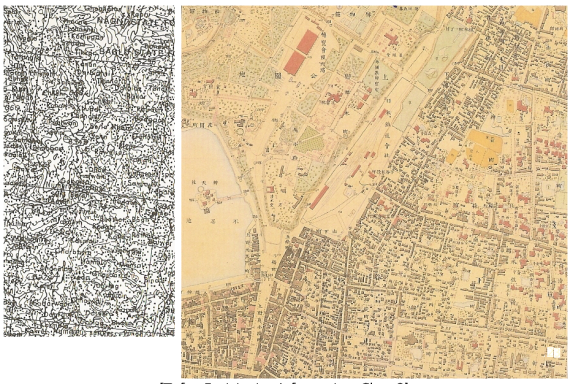
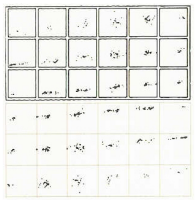
Layering: Cartography



Layering: Backgrounds

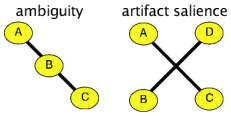
want subtler background than foreground



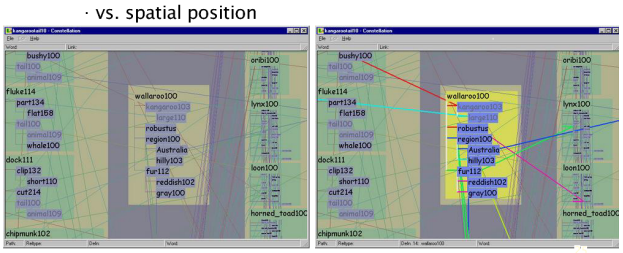
[Tufte, Envisioning Information, Chap 3]

Layering: Graphs

edge crossing problem
- false attachments



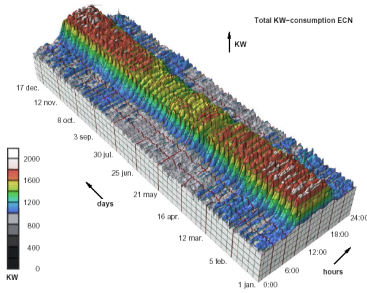
layers to avoid perception
- vs. spatial position



[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



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

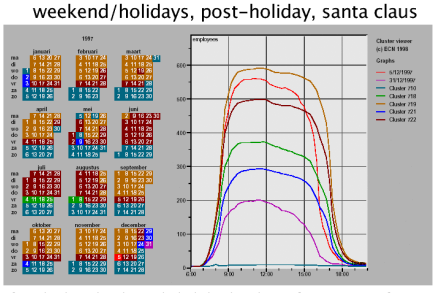
start with all M day patterns
- compute mutual differences, merge most similar
- continue up to 1 root cluster

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

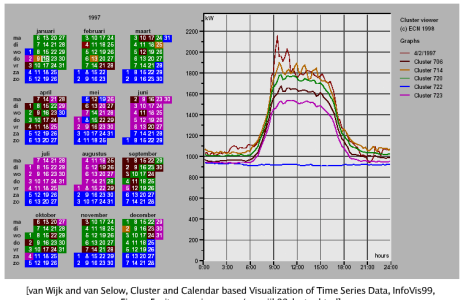
linked 2D calendar+clusters shows patterns
- plot: number of employees vs. time of day
  office hours, fridays/summer, school break, weekend/holidays, post-holiday, santa claus



[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

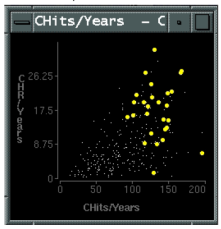
meaningful derived space: clusters

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.]

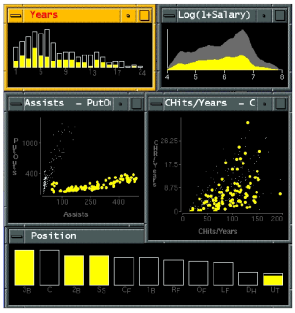
Linked Highlighting

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

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

Linked Highlighting

Exploratory Data Visualizer



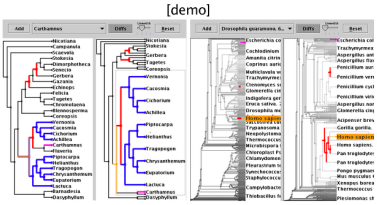
[Visual Exploration of Large Structured Databases, Graham J. Wills, in New Techniques and Trends in Statistics, pp 237–246, IOS Press 1995.]

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

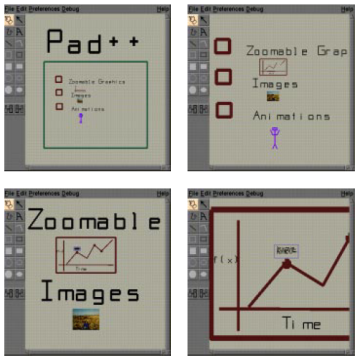
spatial memory / environmental cognition
- city: landmark/path/whole

[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

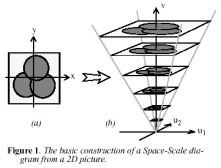
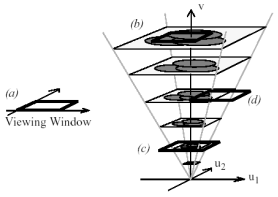


Figure 1. *The basic construction of a Space-Scale diagram from a 2D picture.*

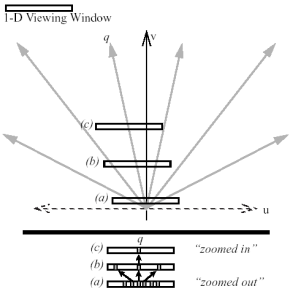
[Space-Scale Diagrams: Understanding Multiscale Interfaces
George Furnas and Ben Bederson, Proc SIGCHI '95.
www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

Viewing Window



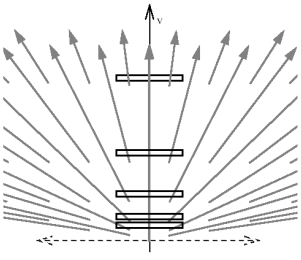
[www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

1D Version



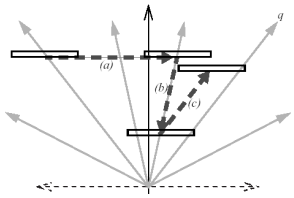
[www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

Multiscale Display



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

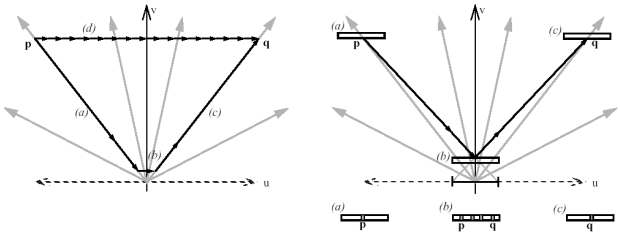
Pan-Zoom Trajectories



[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

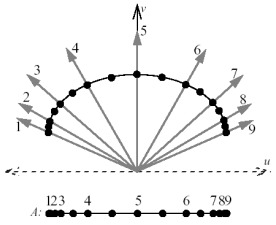
automatic zoom calculated from pan distance

[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



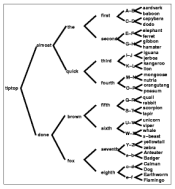
example of Focus+Context

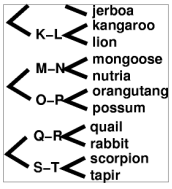
[www.cs.umd.edu/hcil/pad++/papers/chi-95-spacescale/chi-95-spacescale.pdf]

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

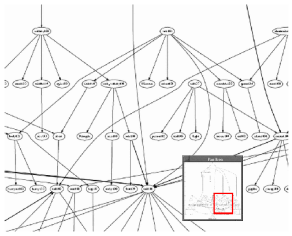




global overview local detail

Overview and Detail

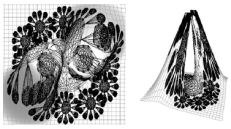
two windows: add linked overview
- cognitive load to correlate



solution
- merge overview and detail into combined view

Single Combined View: Many Names

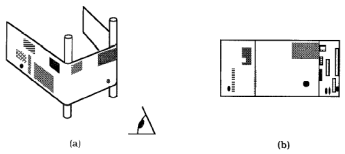
- distortion-oriented presentation techniques
  - [Leung94]
- elastic presentation spaces
  - [Carpendale01]
- fisheye views
  - [Furnas86,Sarkar94]
- focus+context
  - [Rao94]
- hyperbolic views
  - [Rao95, Munzner97]
- nonlinear distortion
  - [Keahey97]
- pliable surfaces
  - [Carpendale95]
- stretchable rubber sheet
  - [Sarkar93, Robertson93, Munzner03]



Focus+Context Intuition

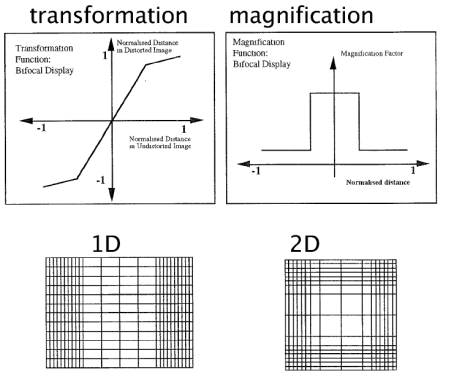
stretch surface: move part closer to eye

- Bifocal Display, Perspective Wall



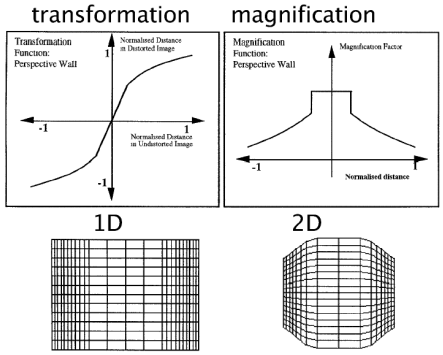
[A Review and Taxonomy of Distortion-Oriented Presentation Techniques. Leung and Apperley, www.ai.mit.edu/people/jimmylin/papers/Leung94.pdf]

Bifocal



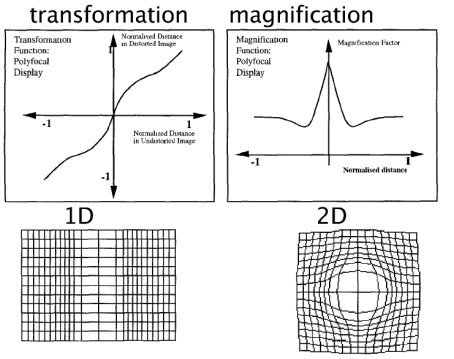
[A Review and Taxonomy of Distortion-Oriented Presentation Techniques]

Perspective Wall



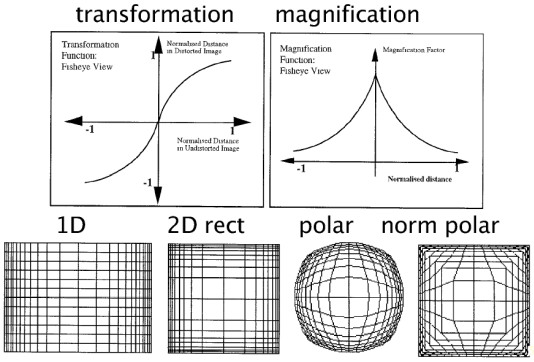
[A Review and Taxonomy of Distortion-Oriented Presentation Techniques]

Polyfocal: Continuous Mag



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

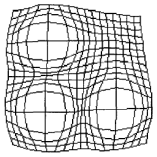
Fisheye Views: Continuous Mag



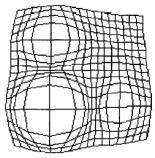
[A Review and Taxonomy of Distortion-Oriented Presentation Techniques]

Multiple Foci

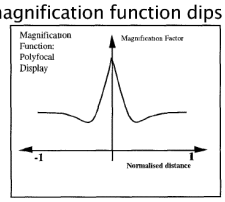
same params



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

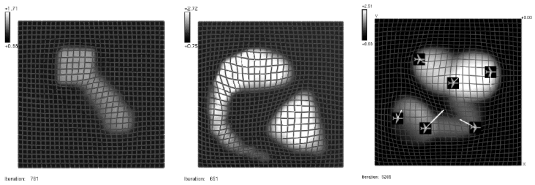
new mathematical framework
- approximate integration, iterative refinement
- minimize "error mesh"

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

Nonlinear Magnification Expressiveness

magnification is more intuitive control

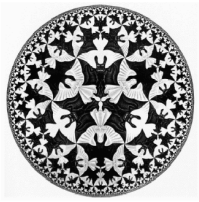
- allow expressiveness, data-driven expansion

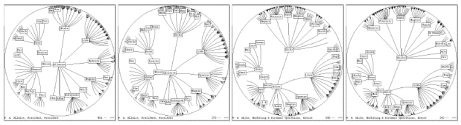


[Nonlinear Magnification Fields. Alan Keahey, Proc InfoVis 1997
ftp://ftp.cs.indiana.edu/pub/tkeahey/papers/infovis.97.pdf]

2D Hyperbolic Trees

fisheye effect from hyperbolic geometry





[The Hyperbolic Browser: A Focus + Context Technique for Visualizing Large Hierarchies. John

3D Hyperbolic Graphs: H3

3D hyperbolic geometry, tree as backbone

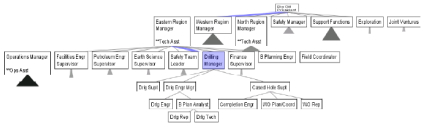
[video]
[graphics.stanford.edu/videos/h3]

[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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