Seeing, Hearing, and Touching: 
Putting It All Together

Seeing Module

Rapid Vision
Visual Encoding
Procedural Vision
Navigating Visual Space

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SIGGRAPH 2004
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

\[ 57 \times 48 \]
External Representation: multiplication

paper   mental buffer

\[
\begin{array}{c}
57 \\
\times 48 \\
\end{array}
\begin{array}{c}
\_\_\_ \\
[7 \times 8 = 56]\end{array}
External Representation: multiplication

division
mental buffer

\[
\begin{array}{c}
5 \\
57 \\
x 48 \\
\hline
\end{array}
\]

[ 7\times 8 = 56 ]

6
External Representation: multiplication

\[
\begin{array}{c}
\frac{5}{57} \\
\times 48 \\
\hline
\end{array}
\]

[5*8=40 + 5 = 45]

6
External Representation: multiplication

paper mental buffer

\[
\begin{array}{c}
\text{57} \\
\times \text{48} \\
\end{array}
\]

\[5 \times 8 = 40 + 5 = 45\]

456
External Representation: multiplication

\[ \begin{array}{c}
57 \\
\times 48 \\
\hline \\
456 \\
\end{array} \]

[7*4=28]
External Representation: multiplication

paper  mental buffer

\[
\begin{array}{c}
\begin{array}{c}
2 \\
57 \\
x 48 \\
\hline \\
456 \\
8
\end{array} \\
[7 \times 4 = 28]
\end{array}
\]
External Representation: multiplication

\[
\begin{array}{c}
2 \\
57 \\
\times 48 \\
\hline
\end{array}
\]

\[
[5 \times 4 = 20 + 2 = 22]
\]

456
8

paper \hspace{1cm} \text{mental buffer}
External Representation: multiplication

paper       mental buffer

\[
\begin{array}{c}
57 \\
\times 48 \\
\hline
\text{[5*4=20 + 2 =22]}
\end{array}
\]

456
228
External Representation: multiplication

57
x 48

456
228

6
External Representation: multiplication

paper          mental buffer

\[
\begin{array}{c}
  57 \\
  \times \quad 48 \\
\end{array}
\]

\[
\begin{array}{c}
  456 \\
  228 \\
  6 \\
\end{array}
\]

[8+5 = 13]
External Representation: multiplication

paper       mental buffer

\[
\begin{array}{c}
57 \\
\times 48 \\
\hline
1 \\
\hline
456 \\
\hline
228 \\
\hline
36
\end{array}
\]

[8+5 = 13]
External Representation: multiplication

\[
\begin{array}{c}
57 \\
\times 48 \\
\hline
1 \\
456 \\
\hline
228 \\
\hline
36 \\
\end{array}
\]

[4+2+1=7]
External Representation: multiplication

| paper | mental buffer |

\[
\begin{array}{c}
57 \\
\times 48 \\
\hline
456 \\
258 \\
\hline
736
\end{array}
\]

\[4+2+1=7]
External Representation: multiplication

paper mental buffer

\[
\begin{array}{c}
57 \\
\times 48 \\
\end{array}
\]

\[
\begin{array}{c}
456 \\
258 \\
2736 \\
\end{array}
\]
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

[Layering: Graphs by 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, weekends/holidays, post-holiday, santa claus

![Calendar and Graphs]

[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, citeeseer.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/linewdith, motion

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
Linked Highlighting

Exploratory Data Visualizer

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

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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++

[Images of interface elements showing options for Zoomable Graphics, Images, Animations, Zoomable Graphs, Images, Animations, and a graph over time]
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.
Viewing Window

1D Version

Multiscale Display

Pan–Zoom Trajectories

Shortest Path

anisotropic cost: zooming vs. panning

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
www-ui.is.s.u-tokyo.ac.jp/~takeo/papers/uisst2000.pdf]
Fisheye View

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
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

Bifocal

transformation

magnification

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

transformation

[Diagram showing transformation function: Perspective Wall]

magnification

[Diagram showing magnification function: Perspective Wall]

1D

[Grid showing 1D perspective wall transformation]

2D

[Grid showing 2D perspective wall transformation]

[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 Expressiveness

magnification is more intuitive control

- allow expressiveness, data-driven expansion

2D Hyperbolic Trees

fisheye effect from hyperbolic geometry
3D Hyperbolic Graphs: H3

3D hyperbolic geometry, tree as backbone

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

focus+context tree  [demo]

- interactively expand/contract, not stretching space

More Reading: Layering, Highlighting

Chapter 3: Layering and Separation

Interactive Visualization of Large Graphs and Networks
Chapter 5, Constellation: Linguistic Semantic Networks
Tamara Munzner, PhD thesis, Stanford University, 2000, pp 87–122

Cluster and Calendar based Visualization of Time Series Data
http://citeseer.nj.nec.com/vanwijk99cluster.html

Brushing Scatterplots, Becker and Cleveland
Reprinted in Dynamic Graphics for Data Analysis, edited by W. S.

Visual Exploration of Large Structured Databases, Graham J. Wills, in

TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility.
Tamara Munzner et al, SIGGRAPH 2003.
http://www.cs.ubc.ca/~tmm/papers/tj
More Reading: Navigation, Zooming

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

Rapid Controlled Movement Through a Virtual 3D Workspace
Jock Mackinlay, Stuart Card, and George Robertson.
Proc SIGGRAPH '90, pp 171-176.

Pad++: A Zooming Graphical Interface for Exploring Alternate Interface Physics
Ben Bederson and James D. Hollan, Proc UIST 94

Space-Scale Diagrams: Understanding Multiscale Interfaces
George Furnas and Ben Bederson, Proc SIGCHI '95.

Speed-Dependent Automatic Zooming for Browsing Large Documents
Takeo Igarashi and Ken Hinckley, Proc. UIST'00, pp. 139-148.

Smooth and Efficient Zooming and Panning.
More Reading: Focus+Context


More Reading: Focus+Context

A Framework for Unifying Presentation Space.
M. S. T. Carpendale and C. Montagnese., Proc. UIST 01, p 61–70.

3-Dimensional Pliable Surfaces: for the Effective Presentation of Visual Information


The Table Lens: Merging Graphical and Symbolic Representations in an Interactive
Focus+Context Visualization for Tabular Information

The Document Lens, George G. Robertson and Jock D. Mackinlay,
Proc UIST 93, p 101–108

Graphical fisheye views. Manojit Sarkar and Marc H. Brown,

Stretching the Rubber Sheet: A Metaphor for Viewing Large Layouts on Small Screens.
Manojit Sarkar, Scott S. Snibbe, Oren J. Tversky and Steven P. Reiss.
Proc. UIST 93, p 81–91.