Information Visualization

interactive visual representation of abstract data
Interactivity

static images
  · 10,000 years
  · art, graphic design

moving images
  · 100 years
  · cinematography

interactive graphics
  · 20 years
  · computer graphics, human–computer interaction
Information Visualization

interactive visual representation of abstract data
  · help human perform some task more effectively
Task–Oriented Design: Constellation

custom design for checking semantic networks
  · reading definition subgraph labels
  · following paths through network
Task-Oriented Design

previous general methods

[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#dotconstfig]
Information Visualization

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

bridging many fields
  · graphics: interacting in realtime
  · cognitive psych: finding appropriate representation
  · HCI: using task to guide design and evaluation

external representation
  · reduces load on working memory
  · offload cognition

  · familiar example: multiplication/division
External Representation: multiplication

57
x 48
---
External Representation: multiplication

paper  mental buffer

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

[ 7*8=56 ]
External Representation: multiplication

paper

mental buffer

\[
\begin{array}{c}
5 \\
57 \\
x 48 \\
\hline
6
\end{array}
\]

[ 7*8=56 ]
External Representation: multiplication

\[
\begin{array}{c}
5 \\
57 \\
\times 48 \\
\hline
6 \\
\end{array}
\]

[5*8=40 + 5 = 45]
External Representation: multiplication

paper: mental buffer

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

[5*8=40 + 5 = 45]
External Representation: multiplication

paper                  mental buffer

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

[7 \times 4 = 28]  

456
External Representation: multiplication

Paper

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

\[ 456 \]

\[ 8 \]

Mental buffer

\[ 7 \times 4 = 28 \]
External Representation: multiplication

paper  mental buffer

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

[5*4=20 + 2 =22]

456
8
External Representation: multiplication

paper                      mental buffer

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

[5*4=20 + 2 =22]
External Representation: multiplication

paper         mental buffer

\[
\begin{array}{c}
57 \\
\times 48 \\
\hline
456 \\
228 \\
\hline
6 \\
\end{array}
\]
External Representation: multiplication

| paper | mental buffer |

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

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

[8+5 = 13]
External Representation: multiplication

paper       mental buffer

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

\[
\begin{array}{c}
1 \\
456 \\
228 \\
\end{array}
\]

[8+5 = 13]

36
External Representation: multiplication

paper  mental buffer

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

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

paper    mental buffer

57
\times 48

\begin{array}{c}
456 \\
258 \\
\end{array}
\quad \quad [4+2+1=7]

736
External Representation: multiplication

paper  mental buffer

\[
\begin{array}{c}
57 \\
\times 48 \\
\hline
456 \\
258 \\
\hline
2736
\end{array}
\]
Information Visualization

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

bridging many fields
  · graphics: interacting in realtime
  · cognitive psych: finding appropriate representation
  · HCI: using task to guide design and evaluation

external representation
  · reduces load on working memory
  · offload cognition

  · familiar example: multiplication/division
  · infovis example: topic graphs
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
minimal attention to read answer
External Rep: Automatic Layout

manual: hours, days

automatic: seconds

[Godel, Escher, Bach. Hofstader 79]
dot, [Gansner et al 93]
InfoVis vs. SciVis

is spatialization given (scivis) or chosen (infovis)
  · my definition

names are unfortunate historical accidents
  · not scivis iff data generated by scientists
  · infovis not unscientific
  · scivis not uninformative
  · but – too late to change

infovis: how to represent
  · choosing, doing, evaluating
  · huge space of possibilities: random walk ineffective
  · need design guidelines
Overviews: mantra

overview

[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahlberg and Shneiderman, Proc SIGCHI '94, citeseer.ist.psu.edu/ahlberg94visual.html]
Overviews: mantra
overview, zoom and filter

Ahlberg & Shneiderman, Color plate 2. Categories have been selected, the displayed is zoomed

[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahlberg and Shneiderman, Proc SIGCHI '94, citeseer.ist.psu.edu/ahlberg94visual.html]
Overviews: mantra

overview, zoom and filter, details-on-demand

[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahlberg and Shneiderman, Proc SIGCHI '94, citeeseer.ist.psu.edu/ahlberg94visual.html]
Overviews: Shneiderman mantra

overview first,
then zoom and filter,
details–on–demand

Overviews: Rivet

performance tuning
· levels of detail

3 We are able to focus the area of interest to 2000 cycles -- few enough cycles that we can use animation for further investigation.

4 The instruction mix chart lets us see what types of instructions are in the pipeline during the time interval of interest.

2 There are periods of increased pipeline stall throughout the execution.

1 The overview displays stall and throughput information for the entire execution.

[Stolte et al, Visualizing Application Behavior on Superscalar Processors, InfoVis 99, graphics.stanford.edu/papers/rivet_pipeline]
Overviews: SeeSoft

software maintenance

- colored lines of code → lines one pixel high

code age

platform dependencies

[Ball and Eick, Software Visualization in the Large, Computer 29:4, 1996
citeser.nj.nec.com/ball96software.html]
Overviews: VisDB

database queries
separate attributes
grouped attributes

Overview+Detail

problem
  · avoid user disorientation when inspecting detail
  · hard for big datasets

bad: one window, must remember position

global overview

local detail
Overview+Detail

better: add linked overview window(s)
problem: still cognitive load to correlate
Focus+Context

merge overview, detail into single window
  ∙ fisheye views [Furnas 86], [Sarkar et al 94]
  ∙ nonlinear magnification [Keahey 96]

[Alan Keahey. www.cs.indiana.edu/~tkeahey/research/nlm/nlm.html]
Focus + Context: Hyperbolic Trees

fisheye effect from 2D hyperbolic geometry

[demo: www.lexisnexis.com/startree]

Focus + Context: H3

fisheye effect from 3D hyperbolic geometry

[demo: graphics.stanford.edu/~munzner/h3]

Focus+Context: TreeJuxtaposer

stretch and squish "rubber sheet"
guaranteed visibility
  • keeping highlighted marks visible at all times
  • [demo: olduvai.sf.net/tj]

Focus+Context: SpaceTree

interactively expand/contract
- not stretching space
- [demo: www.cs.umd.edu/hcil/spacetree]

3D Extrusion: Obvious but Nonoptimal

Perspective interferes with comparison daily, weekly patterns hard to see

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

2D linked clusters–calendars shows patterns
- office hours, weekend/holidays, summer/fridays
- school break, 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]
Preattentive Visual Channels: Popout

color (hue) alone: preattentive
  - visual attentional system not invoked
  - parallel search: speed independent of distractor count

[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]
Preattentive Visual Channels: Popout

many preattentive channels of visual modality

- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction
- [and many more...]

[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]
Non-preattentive: parallelism

many preattentive channels of visual modality
  · hue
  · shape
  · texture
  · length
  · width
  · size
  · orientation
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  · intersection
  · intensity
  · flicker
  · direction of motion
  · stereoscopic depth
  · lighting direction
  · [and many more...]

[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]
Preattentive Visual Channels

color alone: preattentive
shape alone: preattentive

combined hue and shape: not preattentive

- requires attention
- sequential search: speed linear with distractor count

[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]
Data Types

Continuous (quantitative)
- 10 inches, 17 inches, 23 inches

Ordered (ordinal)
- small, medium, large

Categorical (nominal)
- apples, oranges, bananas
Data Type Affects Channel Ranking

spatial position best for all types
  · accuracy at judging magnitudes, from best to worst

[MacKinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]
Nonlinear Perception of Magnitudes

sensory channels **not** equally discriminable

Stevens’ Power Law: \( I = S^p \)

Channel Dynamic Range

linewidth: limited discriminability, but useful

[mappa.mundi.net/maps/maps_014/telegeography.html]
Integral vs. Separable Channels

red–green  x–size  size  color  color  color
yellow–blue  y–size  orientation  shape  motion  location

[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]
Coloring Categorical Data

22 colors, but only ~8 distinguishable
Coloring Categorical Data

discrete small patches separated in space

limited distinguishability: around 8–14
  · channel dynamic range: low
  · choose bins explicitly for maximum milage

maximally discriminable colors from Ware
  · maximal saturation for small areas

[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999. Figure 4.21]
Minimal Saturation for Large Areas

avoid saturated color in large areas
· "excessively exuberant"

[Edward Tufte, Envisioning Information, p.82]
Minimal Saturation for Large Areas

- large continuous areas in pastel
- diverging colormap (bathymetric/hypsometric)

[Tufte, Envisioning Information, p. 91]
Coloring Ordered Data

innate visual order

· greyscale/luminance

· saturation

· brightness

debatable visual order

· hue
Coloring Quantitative Data

continuous field

side by side patches highly distinguishable
- channel dynamic range: high

mediocre
- hue (rainbow)

good
- greyscale/luminance
- saturation
- brightness

[www.research.ibm.com/visualanalysis/perception.html]
Rainbow Colormap Advantages

low-frequency segmentation
  - "the red part", "the orange part", "the green part"

Rainbow Colormap Disadvantages

segmentation artifacts: perceptually nonlinear!

(partial) solution: perceptually isolinear map


Non-Rainbow Colormap Advantages

high-frequency continuity
  - interpolating between just two hues

Color Deficiency

very low channel dynamic range for some!

protanope
deuteranope
  · has red/green deficit
  · 10% of males!

tritanope
  · has yellow/blue deficit

http://www.vischeck.com/vischeck
  · test your images
Color Deficiency Examples: vischeck

Designing Around Deficiencies

red/green could have domain meaning then distinguish by more then hue alone
- redundantly encode with saturation, brightness

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<th>Status</th>
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[Courtesy of Brad Paley]
Space vs. Time: Showing Change

 literal \[\leftarrow \text{time for time} \rightarrow \text{space for time} \rightarrow\] abstract

 animation: show time using temporal change
   · good: show process

[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]
Space vs. Time: Showing Change

literal ← time for time → abstract

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  · good: compare by flipping between two things

[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]
[www.astroshow.com/ccdpho/pluto.gif]
Space vs. Time: Showing Change

literal
<-----------------------------
time for time
abstract
--------------------------------
space for time

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[www.astroshow.com/ccdpho/pluto.gif]
[Edward Tufte. The Visual Display of Quantitative Information, p 172]
Space vs. Time: Showing Change

literal

<--------------------------- abstract

time for time

space for time

animation: show time using temporal change
  · good: show process
  · good: compare by flipping between two things
  · bad: compare between many things
  interference from intermediate frames

[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]
[www.astroshow.com/ccdpho/pluto.gif]
[Edward Tufte. The Visual Display of Quantitative Information, p 172]
Space vs. Time: Showing Change

literal ← time for time → abstract space for time

small multiples: show time using space

- overview: show each time step in array
- compare: side-by-side easier than temporal external cognition instead of internal memory
- general technique, not just for temporal changes

[Edward Tufte. The Visual Display of Quantitative Information, p 172]
More Information

http://www.cs.ubc.ca/~tmm
  · talks, papers, projects: lots of pictures!

UBC Term 1 grad course
  · CPSC 533C Visualization

current project domains
  · bioinformatics, data mining, sustainability

past project domains
  · topology, networking, computational linguistics, ...