Interactive Information Visualization

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Outline

Information Visualization Motivation

Designing for Humans

Information Visualization Techniques
  - Using Color
  - Overviews
  - Space and Time
  - Layering, Minimizing Occlusion

More Information
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

custom design for checking semantic networks
- reading definition subgraph labels

[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#layoutefffig]
Task-Oriented Design

previous general methods
Design Tradeoffs

information density vs. visual salience

[graphics.stanford.edu/papers/munzner_thesis/html/node11.html#noncanonfig]
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

paper          mental buffer

57
x 48
External Representation: multiplication

paper mental buffer

57
x 48 [ 7*8=56 ]
External Representation: multiplication

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

\[
[ 7 \times 8 = 56 ]
\]

6
External Representation: multiplication

57
x 48

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

6
External Representation: multiplication

paper  mental buffer

\[
\begin{array}{c}
57 \\
\times 48 \\
\hline
456
\end{array}
\] [5*8=40 + 5 = 45]
External Representation: multiplication

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

[7*4=28]

456
External Representation: multiplication

\[
\begin{array}{c}
\times 48 \\
257 \\
\hline
456 \\
8
\end{array}
\]

[7*4=28]

paper mental buffer
External Representation: multiplication

paper  mental buffer

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

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

456
8
External Representation: multiplication

paper mental buffer

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

[5\times4=20 + 2 =22]

\[
\begin{array}{c}
456 \\
228 \\
\end{array}
\]
External Representation: multiplication

paper  mental buffer

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

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

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

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

[8+5 = 13]
External Representation: multiplication

paper       mental buffer

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

\[8 + 5 = 13\]
External Representation: multiplication

paper  mental buffer

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

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

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

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

[4+2+1=7]

paper  mental buffer
External Representation: multiplication

```
  57
x 48
```

```
  456
258
```

2736
External Representation

- reduces load on working memory
  - offload cognition

familiar example: multiplication/division

infowis 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 [...]

27
External Representation: topic graphs

offload cognition to visual systems
minimal attention to read answer
Automatic Graph Drawing

manual: hours, days

[Godet, Escher, Bach. Hofstader 79]
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Human Perception

sensors/transducers
  · psychophysics: determine characteristics

relative judgements: strong
absolute judgements: weak

different optimizations than most machines
  · eyes are not cameras
  · visual channels are not nD array
  · (brains are not hard disks)
Preattentive Visual Channels

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

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

many preattentive channels of visual modality

- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction

[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
  · curvature
  · intersection
  · intensity
  · flicker
  · direction of motion
  · stereoscopic depth
  · lighting direction

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

- color alone: preattentive
- shape alone: preattentive
- combined hue and shape: multimodal

- requires attention
- 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
Ranking Varies by Data Type

spatial position best for all types

[MacKinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]
Channel Ranking: Quantitative

[graphics.stanford.edu/courses/cs448b-02-spring/lectures/encoding/walk015.html]
Nonlinear Perception of Magnitudes

sensory channels not equally discriminable

Stevens' Power Law: \( I = S^p \)

Channel Dynamic Range

linewidth: limited discriminability, but useful
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]
Color/Brightness Constancy

segmentation: relative judgements

[courtesy of John McCann, from Stone 2001 SIGGRAPH course graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]
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More Information
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"

[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color?
http://www.research.ibm.com/people/l/lloydt/color/color.HTM]
Rainbow Colormap Disadvantages

- Segmentation artifacts
  - Popular interpolation perceptually nonlinear!

Solution

- Create perceptually isolinear map

Non-Rainbow Colormap Advantages

- high-frequency continuity
  - interpolating between just two hues

[Rogowitz and Treinish, How NOT to Lie with Visualization,
Segmenting Colormaps

explicit rather than implicit segmentation

Color Deficiency

very low channel dynamic range for some!

protanope
deutanope
  · 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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[Courtesy of Brad Paley]
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More Information
Overview + Detail

Problem
- avoid user disorientation when inspecting detail
- hard for big datasets

Bad: one window, must remember position

global overview

local detail

jerboa kangaroo lion
mongoose nutria orangutan possum
quail rabbit scorpion tapir
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: H3

3D fisheye (hyperbolic space)

- [demo]

Focus + Context: TreeJuxtaposer

- stretch and squish "rubber sheet"
- guaranteed visibility
  - keeping highlighted marks visible at all times
  - [demo]

Constructing Overviews

SeeSoft: software maintenance
  · (colormaps: segmented vs. continuous)

code age  platform dependencies

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

Rivet: performance tuning · level of detail

- We are able to focus the area of interest to 2000 cycles -- few enough cycles that we can use animation for further investigation.
- The instruction mix chart lets us see what types of instructions are in the pipeline during the time interval of interest.
- There are periods of increased pipeline stall throughout the execution.
- 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]
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More Information
Space vs. Time: Showing Change

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

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

----------------------------->

space for time

animation: show time using temporal change

- good: show process
- good: compare by flipping between two things

[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mp4]
[www.astroshow.com/ccdpho/pluto.gif]
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

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

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  abstract
<----------------------------->  
time for time  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]
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More Information
Layering: Cartography
Layering: Graphs

edge crossing problem
  · false attachments

layers to avoid perception
  · vs. spatial position

Minimizing Occlusion

bad: Midwestern occlusion

[citeseer.nj.nec.com/becker95visualizing.html]
Minimizing Occlusion

good: show only start and end of lines

[citeseer.nj.nec.com/becker95visualizing.html]
Minimizing Occlusion: 3D vs. 2D

bad: timeseries extrusion pretty but not useful

[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data], Proc. InfoVis99, citeseer.nj.nec.com/vanwijk99cluster.html]
Minimizing Occlusion: 3D vs. 2D

good: linked 2D display
- hierarchical clustering reveals categories

[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, Proc. InfoVis99, citeseer.nj.nec.com/vanwijk99cluster.html]
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http://www.cs.ubc.ca/~tmm
  · talks, papers, projects: lots of pictures!
  Term 1 office hours: 3:45–4:45 Wed FSC 2618

Term 1 course: CPSC 533C Visualization
Term 2 course: CPSC 314 Computer Graphics

current project domains
  · bioinformatics, data mining, sustainability

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