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
- Navigation/Zooming
- Focus+Context
  - Occlusion
  - Highlighting
- Spatial Navigation
  - Zooming
  - Focus+Context

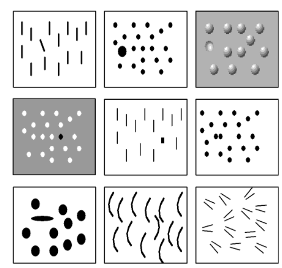
Visual Encoding

represent dataset using perceptual channels

challenges
- rapid processing for only one channel
  - sometimes two

Preattentive Visual Channels

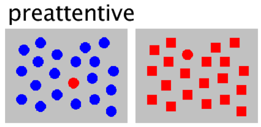
many preattentive channels of visual modality
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction
- and more...



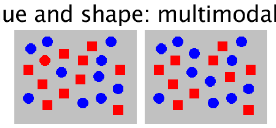
[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP/PP.html]

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/PP.html]

Visual Encoding

represent dataset using perceptual channels

challenges
- rapid processing for only one channel
  - sometimes two
- only some channels separable
  - others integral

Integral vs. Separable Channels

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

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

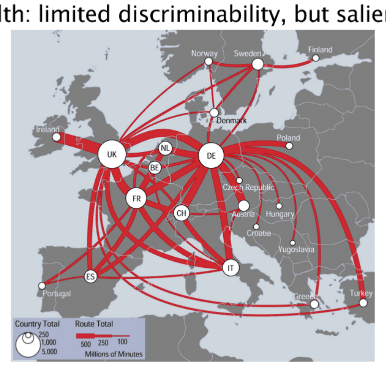
Visual Encoding

represent dataset using perceptual channels

challenges
- rapid processing for only one channel
  - sometimes two
- only some channels separable
  - others integral
- not all channels created equal
  - variable dynamic range

Channel Dynamic Range

linewidth: limited discriminability, but salient



[mappa.mundi.net/maps/maps_014/telegeography.html]

Visual Encoding

represent dataset using perceptual channels

challenges
- rapid processing for only one channel
  - sometimes two
- only some channels separable
  - others integral
- not all channels created equal
  - variable dynamic range

vast parameter space of choices
- need methodology for guidance

information visualization framework
- how to match data variables to visual channel

Overview

Visual Encoding
- Perceptual Channels
- Visualization Frameworks
- Spatial Layout
- Color

Navigating Visual Space
- External Representation
- Navigation/Zooming
- Focus+Context
  - Occlusion
  - Highlighting
- Spatial Navigation
  - Zooming
  - Focus+Context

Framework

Data Variables
- 1D, 2D, 3D, 4D, 5D, ..., ND

Geometric Primitives/ Marks
- point, line, area, surface, volume

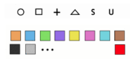
Perceptual Channels/ Retinal Properties
- size, brightness, color, texture, orientation, shape,...
- parameters control appearance of marks
- channels of information flowing from retina to brain

Data Types
- nominal, ordered, quantitative

[Mackinlay/Card; Bertin; Wilkinson; Stolte et al]

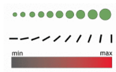
Data Types

categorical (nominal)
- apples, oranges, bananas



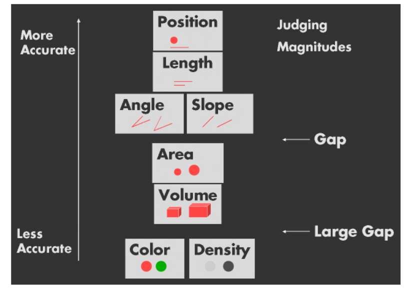
ordered (ordinal)
- small, medium, large
- days: Sun, Mon, Tue, Wed, Thu, Fri, Sat

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



[graphics.stanford.edu/papers/polaris]

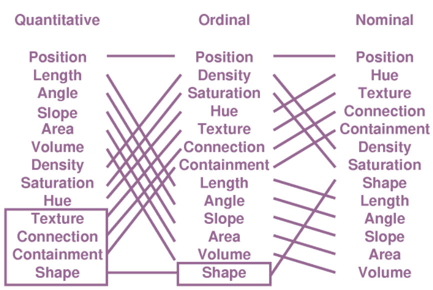
Ranked Perceptual Channels, Quantitative Data



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

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]

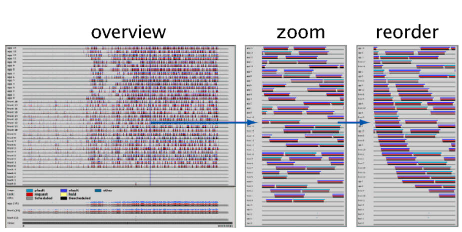
Overview

Visual Encoding
- Perceptual Channels
- Visualization Frameworks
- Spatial Layout
- Color

Navigating Visual Space
- External Representation
- Navigation/Zooming
- Focus+Context
  - Occlusion
  - Highlighting
- Spatial Navigation
  - Zooming
  - Focus+Context

Interactive Ordering: Rivet

performance analysis of parallel system



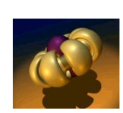
[Bosch, Performance Analysis and Visualization of Parallel Systems Using SimOS and Rivet: A Case Study, HPCA6, 2000. graphics.stanford.edu/papers/rivet_argus]

Space vs. Time: Showing Change

literal <--> abstract

time for time — space for time

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



[www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]

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

[www.geom.uiuc.edu/docs/outreach/oi/evert.mpg] [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

[www.geom.uiuc.edu/docs/outreach/oi/evert.mpg] [www.astroshow.com/ccdpho/pluto.gif]

Space vs. Time: Showing Change

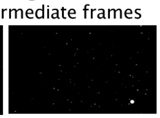
literal ———————————————— abstract

<--------------------------------------->

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
  - change blindness from intermediate frames

[www.geom.uiuc.edu/docs/outreach/oi/evert.mpg] [www.astroshow.com/ccdpho/pluto.gif]

Space vs. Time: Showing Change

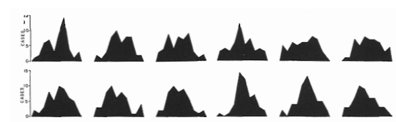
literal ———————————————— abstract

<--------------------------------------->

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]

Overview

Visual Encoding

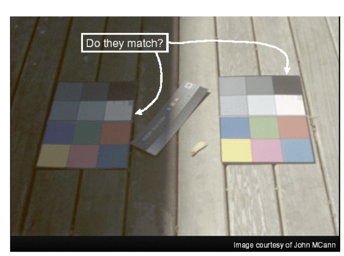
- Perceptual Channels
- Visualization Frameworks
- Spatial Layout
- Color

Navigating Visual Space

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

Color/Brightness Constancy

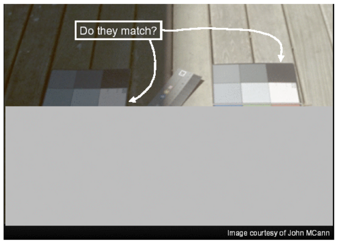
segmentation: relative judgements



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

Color/Brightness Constancy

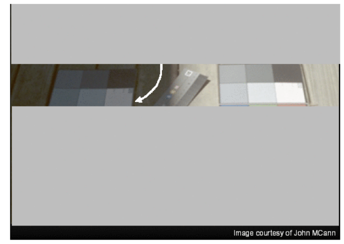
segmentation: relative judgements



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

Color/Brightness Constancy

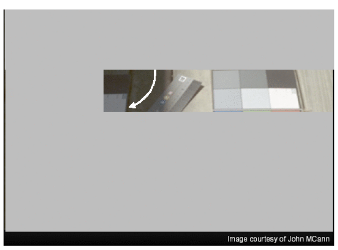
segmentation: relative judgements



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

Color/Brightness Constancy

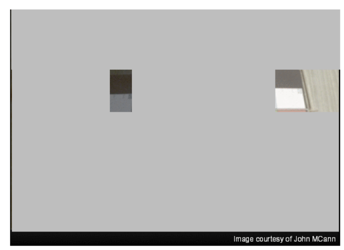
segmentation: relative judgements



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

Color/Brightness Constancy

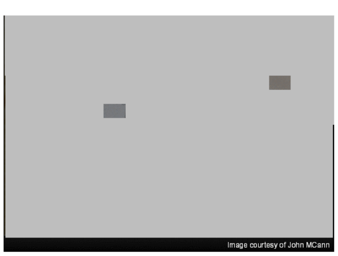
segmentation: relative judgements



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

Color/Brightness Constancy

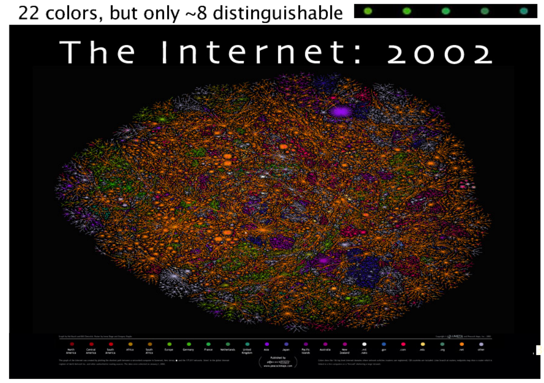
segmentation: relative judgements



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

Coloring Categorical Data

22 colors, but only ~8 distinguishable

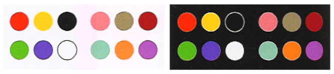


Coloring Categorical Data

discrete small patches separated in space

limited distinguishability: around 8-14
- channel dynamic range: low

maximally discriminable colors from Ware
- maximal saturation for small areas

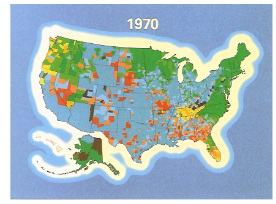


[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999. Figure 4.21]

choose bins explicitly for maximum milage

Minimal Saturation for Large Areas

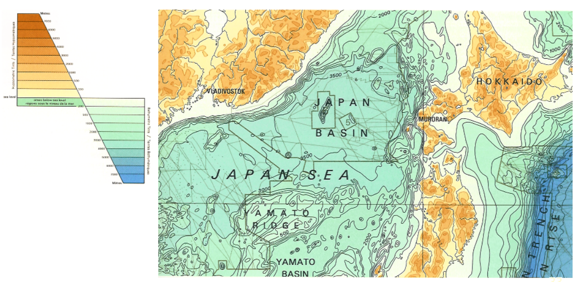
avoid saturated color in large areas
- "excessively exuberant"



[Edward Tufte, Envisioning Information, p.82]

Minimal Saturation for Large Areas

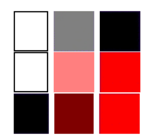
large continuous areas in pastel
- diverging colormap (bathymetric/hypsometric)



[Tufte, Envisioning Information, p.91]

Coloring Ordered Data

innate visual order
- greyscale/luminance
- saturation
- brightness



visual order
- hue

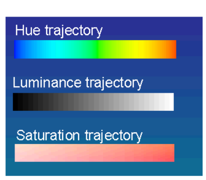
Coloring Quantitative Data

continuous field

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

mediocre
- hue (rainbow)

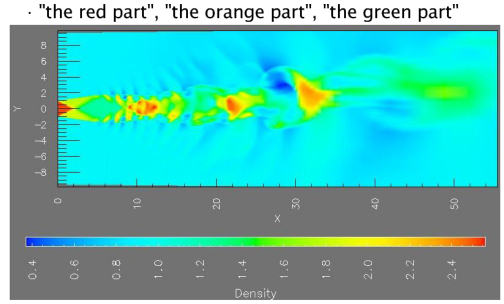
good
- greyscale/luminance
- saturation
- brightness



[www.research.ibm.com/visualanalysis/perception.html]

Rainbow Colormap Advantages

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

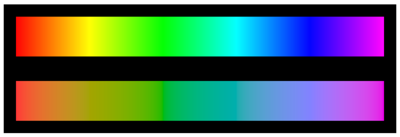


[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color?
http://www.research.ibm.com/people/l/lloydt/color/color.HTM

Rainbow Colormap Disadvantages

segmentation artifacts
- popular interpolation perceptually nonlinear!

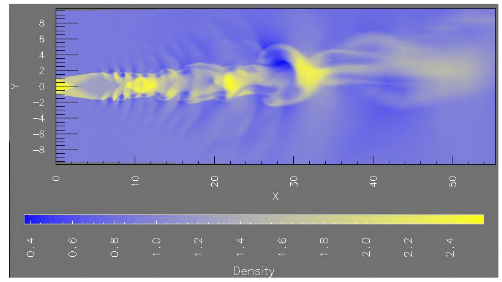
solution
- create perceptually isolinear map



[Kindlmann, Reinhard, and Creem.
Face-based Luminance Matching for Perceptual Colormap Generation. Proc. Vis 02
www.cs.utah.edu/~gk/lumFace]

Non-Rainbow Colormap Advantages

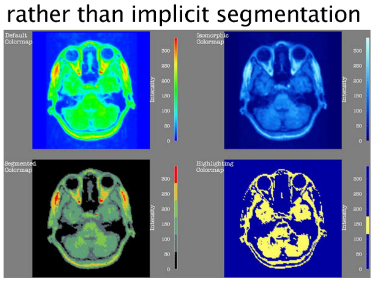
high-frequency continuity
- interpolating between just two hues



[Rogowitz and Treinish, How NOT to Lie with Visualization,
www.research.ibm.com/dx/proceedings/pravda/truevis.htm

Segmenting Colormaps

explicit rather than implicit segmentation



[Rogowitz and Treinish, How NOT to Lie with Visualization,
www.research.ibm.com/dx/proceedings/pravda/truevis.htm

Color Deficiency

very low channel dynamic range for some!

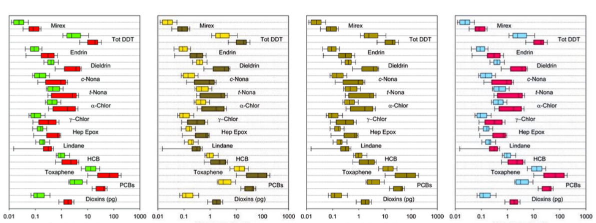
protanope
deutanope
- has red/green deficit
- 10% of males!

tritanope
- has yellow/blue deficit

http://www.vischeck.com/vischeck
- test your images

Color Deficiency Examples: vischeck

original protanope deuteranope tritanope

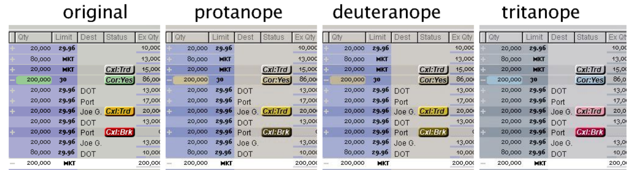


[www.cs.ubc.ca/~tmm/courses/cpsc533c-04-spr/a1/dmitry/533a1.html,
citing Global Assessment of Organic Contaminants in Farmed Salmon,
Ronald A. Hites, Jeffery A. Foran, David O. Carpenter, M. Coreen
Hamilton, Barbara A. Knuth, and Steven J. Schwager, Science 2004 303: 226-229.]

Designing Around Deficiencies

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

original protanope deuteranope tritanope



[Courtesy of Brad Paley]

More Reading: Perceptual Channels

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 5: Visual Attention and Information That Pops Out

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 6: Static and Moving Patterns

The Psychophysics of Sensory Function, S. S. Stevens, Sensory Communication, MIT Press, 1961, pp 1-33.
http://www.cs.ubc.ca/~tmm/courses/cpsc533c-03-spr/readings/ss.pdf

Perception in Visualization. Christopher G. Healey
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

More Reading: Frameworks

Chapter 1, Readings in Information Visualization: Using Vision to Think. Stuart Card, Jock Mackinlay, and Ben Shneiderman, Morgan Kaufmann 1999.

The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. Ben Shneiderman, Proc. 1996 IEEE Visual Languages, also Maryland HCIL TR 96-13
ftp://ftp.cs.umd.edu/pub/hcil/Reports-Abstracts-Bibliography/96-13html/96-13.html

The Structure of the Information Visualization Design Space. Stuart Card and Jock Mackinlay, Proc. InfoVis 97
http://citeseer.nj.nec.com/card96structure.html

The Grammar of Graphics, Leland Wilkinson, Springer 1999

Semiology of Graphics: Diagrams, Networks, Maps. Jaques Bertin.University of Wisconsin Press, Madison (WI), 1983. W. J. Berg (Translator).

More Reading: Spatial Layout

The Visual Design and Control of Trellis Display
R. A. Becker, W. S. Cleveland, and M. J. Shyu
Journal of Computational and Statistical Graphics, 5:123-155. (1996).
http://cm.bell-labs.com/stat/doc/trellis.jcgs.col.ps

Envisioning Information. Edward Tufte. Graphics Press, 1990.
Chapter 4: Small Multiples, Chapter 6: Narratives of Space and Time

The Elements of Graphing Data, William S. Cleveland, Hobart Press 1994.

The Table Lens: Merging Graphical and Symbolic Representations in an Interactive Focus + Context Visualization for Tabular Information
Ramana Rao and Stuart K. Card, SIGCHI '94, pp. 318-322.
http://citeseer.ist.psu.edu/545353.html

Performance Analysis and Visualization of Parallel Systems Using SimOS and Rivet: A Case Study. Robert Bosch, Chris Stolte, Gordon Stoll, Mendel Rosenblum, and Pat Hanrahan. In Proc. Sixth IEEE International Symposium on High-Performance Computer Architecture, Jan 2000. http://graphics.stanford.edu/papers/rivet_argus/

More Reading: Color

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 3: Lightness, Brightness, Contrast, and Constancy

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 4: Color

Envisioning Information. Edward Tufte. Graphics Press, 1990. Chapter 5: Color and Information

How Not to Lie with Visualization, Bernice E. Rogowitz and Lloyd A. Treinish, Computers In Physics 10(3) May/June 1996, pp 268-273.
http://www.research.ibm.com/dx/proceedings/pravda/truevis.htm

A Field Guide To Digital Color, Maureen Stone, AK Peters 2003