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

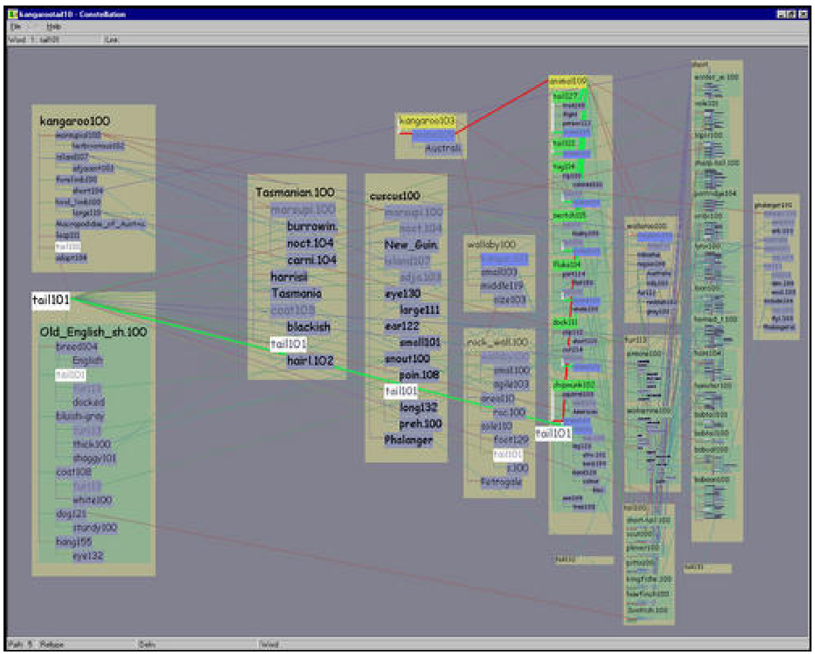
interactive visual representation of abstract data

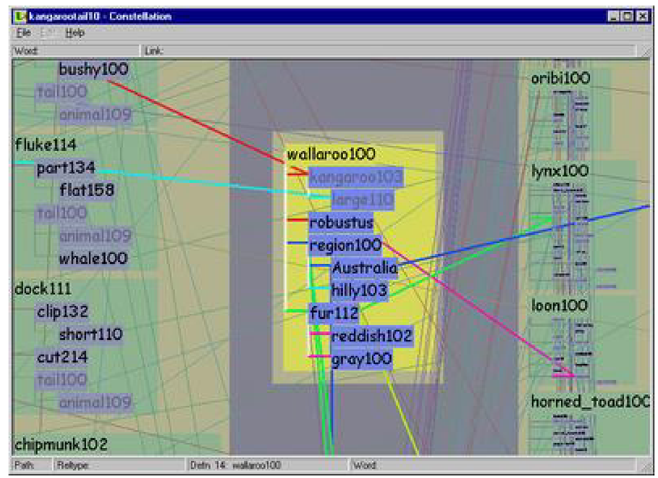
- help human perform some task more effectively

Task-Oriented Design

custom design for checking semantic networks

- reading definition subgraph labels

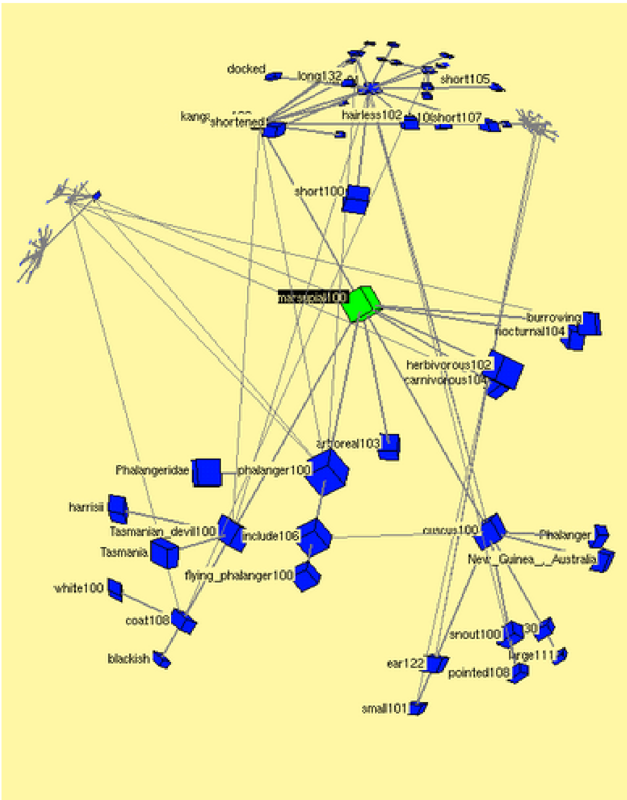


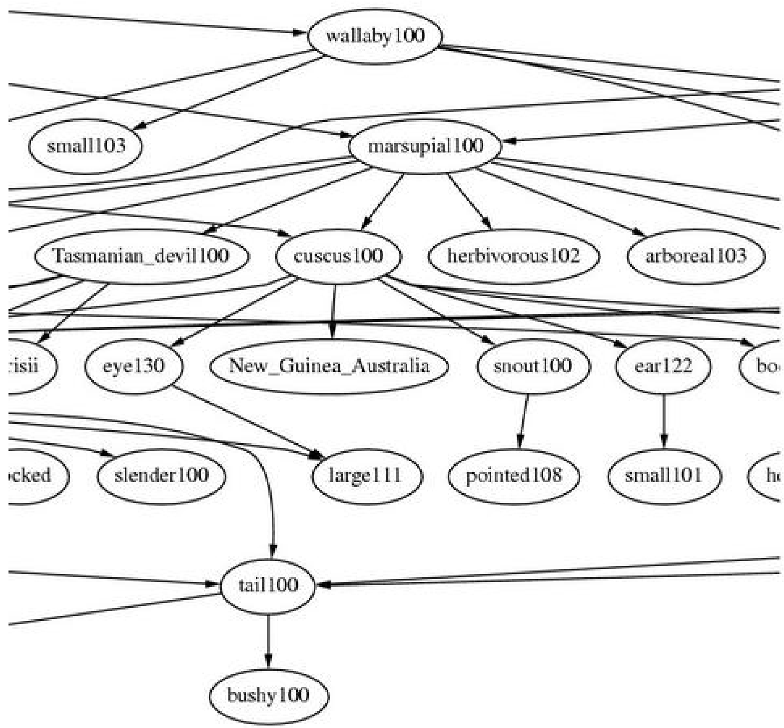


[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#layoutefffig]

Task-Oriented Design

previous general methods

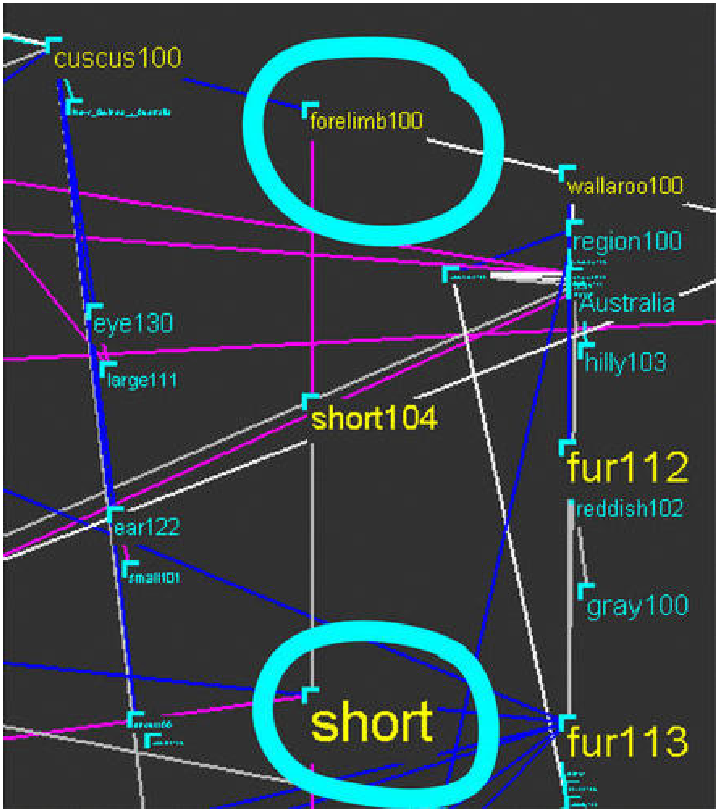


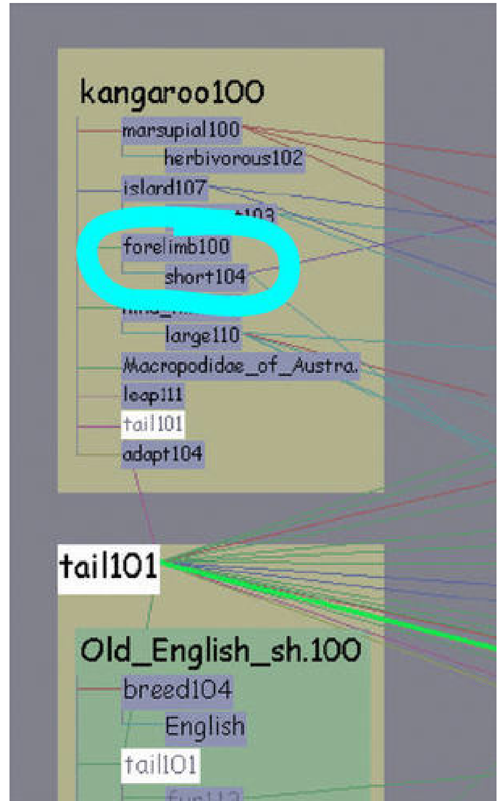


[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#dotconstfig]

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

$$\begin{array}{r} 57 \\ \underline{\times\ 48} \end{array}$$

External Representation: multiplication

paper mental buffer

```
  57
x 48       [ 7*8=56 ]
----
```

External Representation: multiplication

paper

mental buffer

```
   5
  57
x 48
----

   6
```

[7*8=56]

External Representation: multiplication

paper

mental buffer

```
  5
 57
x 48
----

   6
```

[5*8=40 + 5 = 45]

External Representation: multiplication

paper mental buffer

```
   57
 x 48
 ----

  456
```

[5*8=40 + 5 = 45]

External Representation: multiplication

paper | mental buffer

```
  57
x 48       [7*4=28]
----

 456
```

External Representation: multiplication

paper | mental buffer

```
   2
  57
x 48
----

 456
  8
```

[7*4=28]

External Representation: multiplication

paper

mental buffer

```
  2
 57
x48
----

456
 8
```

[5*4=20 + 2 =22]

External Representation: multiplication

paper mental buffer

```
   57
 x 48
 ----

  456
 228
```

[5*4=20 + 2 =22]

External Representation: multiplication

paper mental buffer

```
  57
x 48
----

 456
228
----
   6
```

External Representation: multiplication

paper	mental buffer

```
  57
x 48
----

 456
228_
----
   6
```

[8+5 = 13]

External Representation: multiplication

paper

mental buffer

```
   57
 x 48
 ----
  1
  456
 228
 ----
   36
```

[8+5 = 13]

External Representation: multiplication

paper

mental buffer

```
   57
 x 48
 ----
  1
  456
 228
 ----
   36
```

[4+2+1=7]

External Representation: multiplication

paper — mental buffer

```
   57
 x 48
 ----

  456
 258_
 ----
  736
```

[4+2+1=7]

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

infovis example: topic graphs

External Representation: Topic Graphs

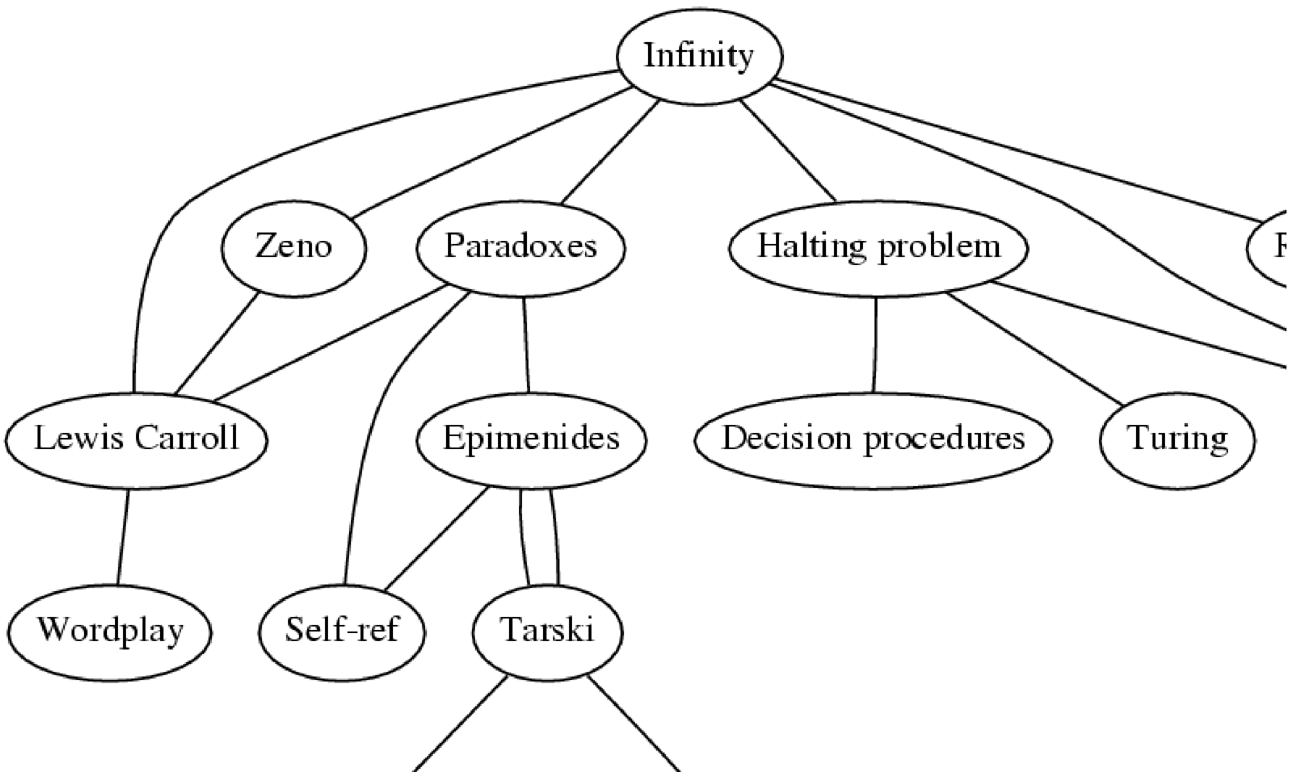
[Godel, Escher, Bach. Hofstadter 1979]

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

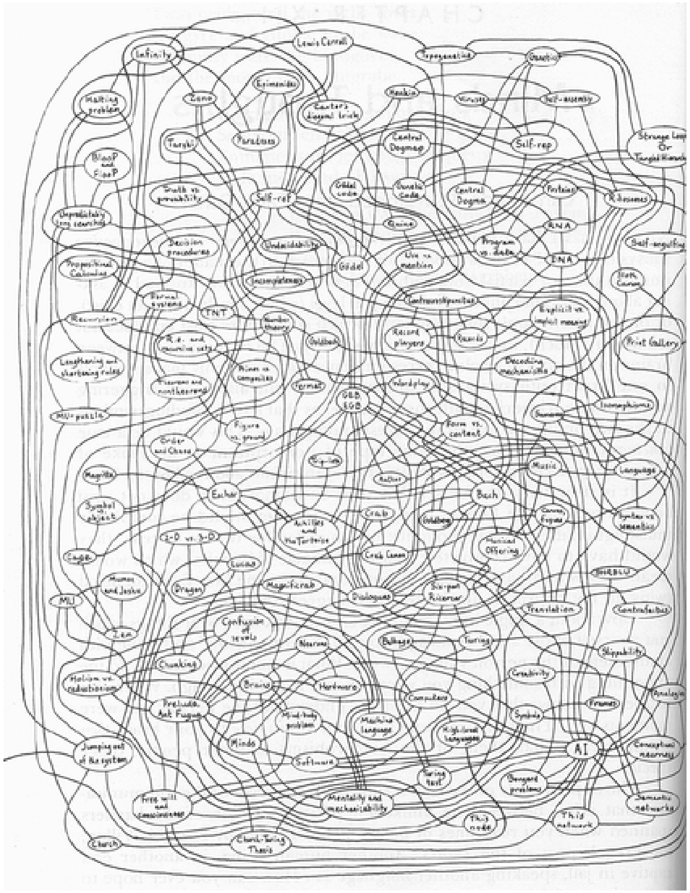
offload cognition to visual systems
minimal attention to read answer



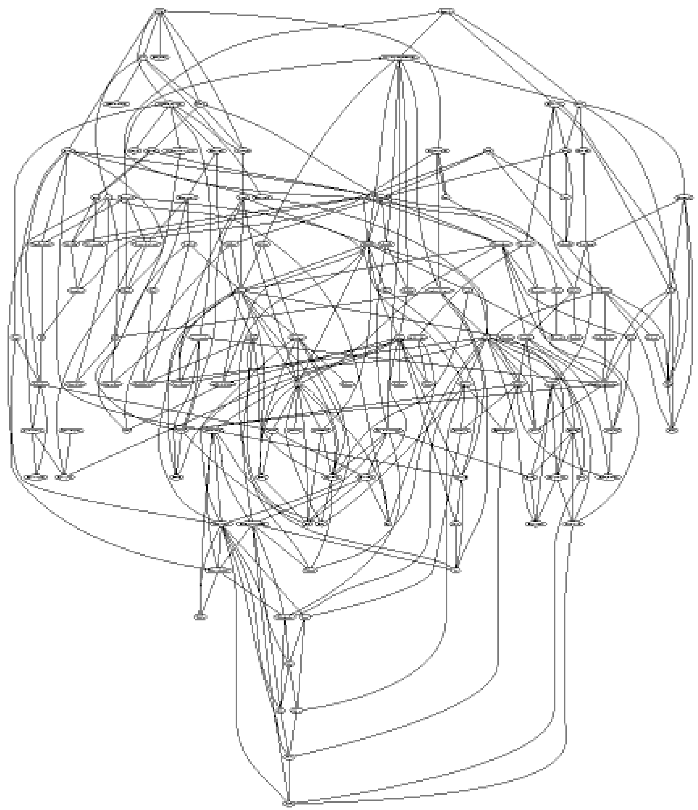
Automatic Graph Drawing

manual: hours, days

automatic: seconds



[Godel, Escher, Bach. Hofstader 79]


dot, [Gansner et al 93]

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Human Perception

sensors/transducers

- psychophysics: determine characteristics

relative judgements: strong
absolute judgements: weak

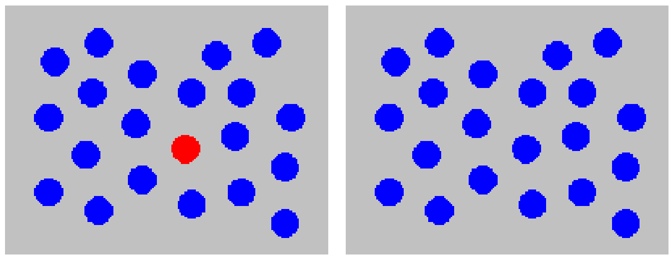
different optimizations than most machines

- 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

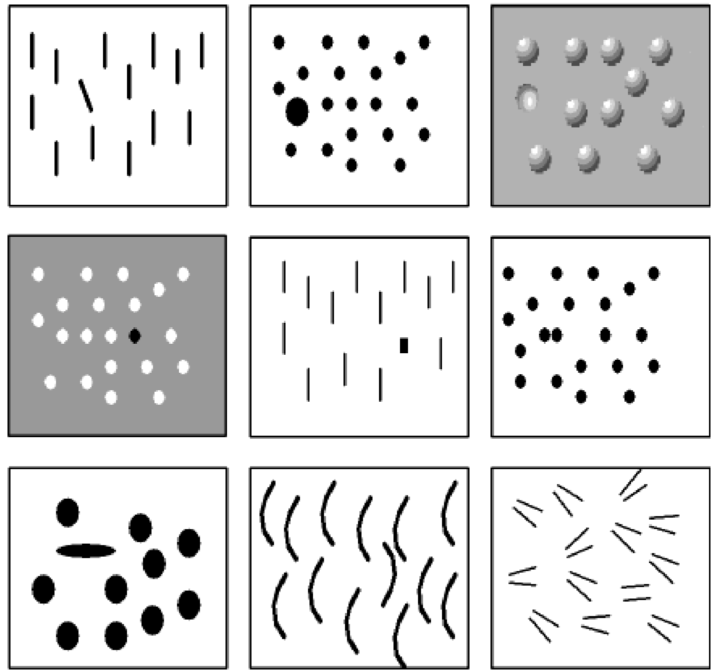


[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]

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
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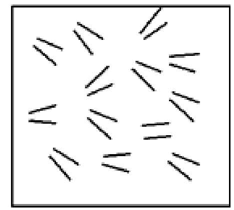
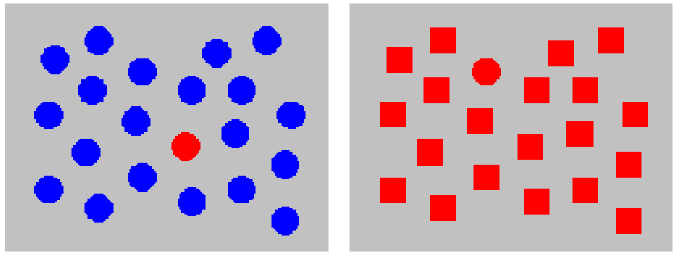


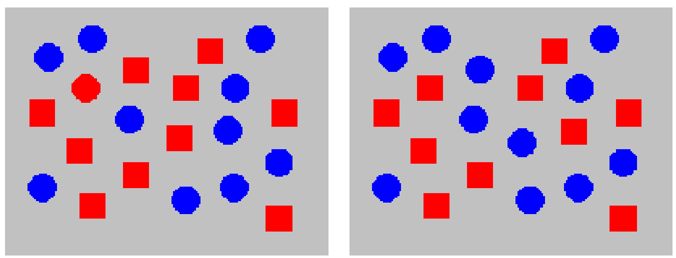
[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]

Preattentive Visual Channels

color alone: preattentive
shape alone: preattentive



combined hue and shape: multimodal



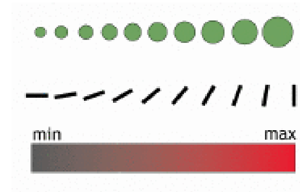
- requires attention
- search speed linear with distractor count

[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

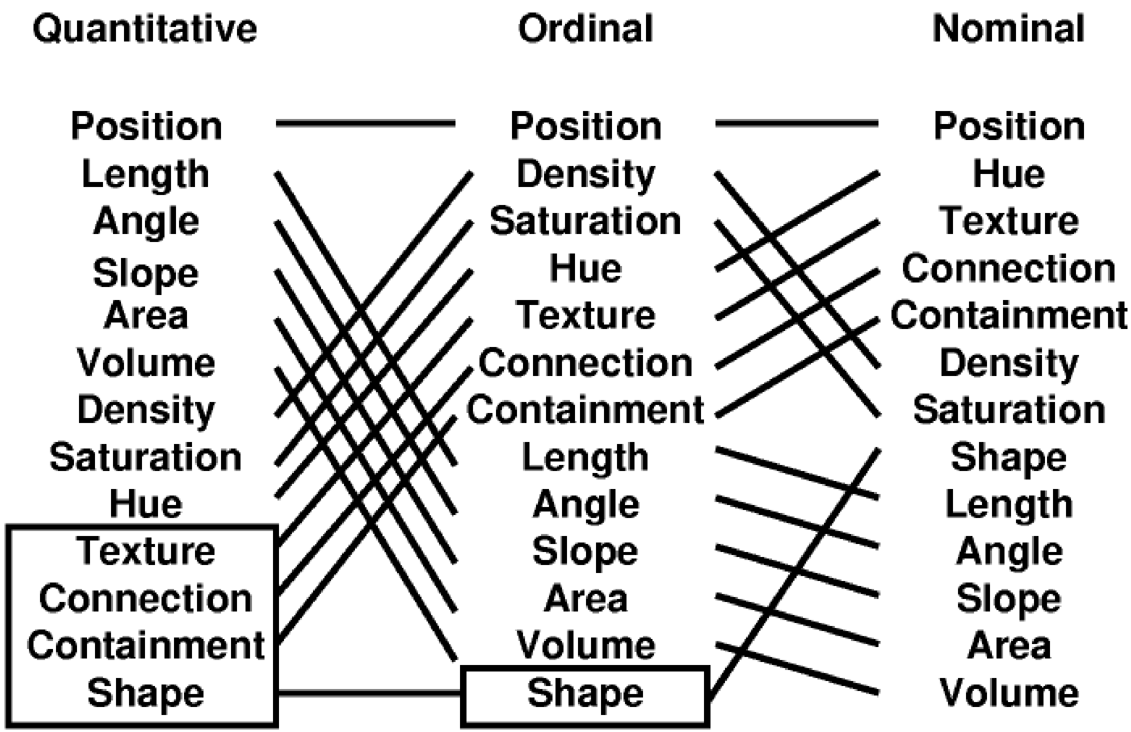
categorical (nominal)

- apples, oranges, bananas

[graphics.stanford.edu/papers/polaris]

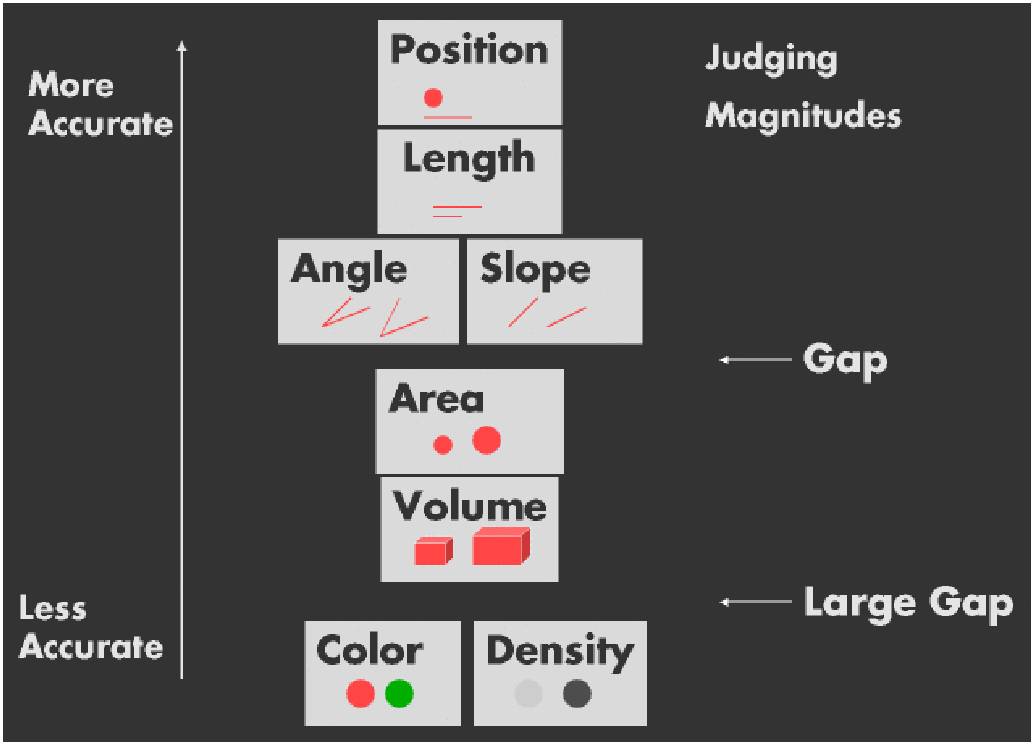
Ranking Varies by Data Type

spatial position best for all types



[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]

Channel Ranking: Quantitative

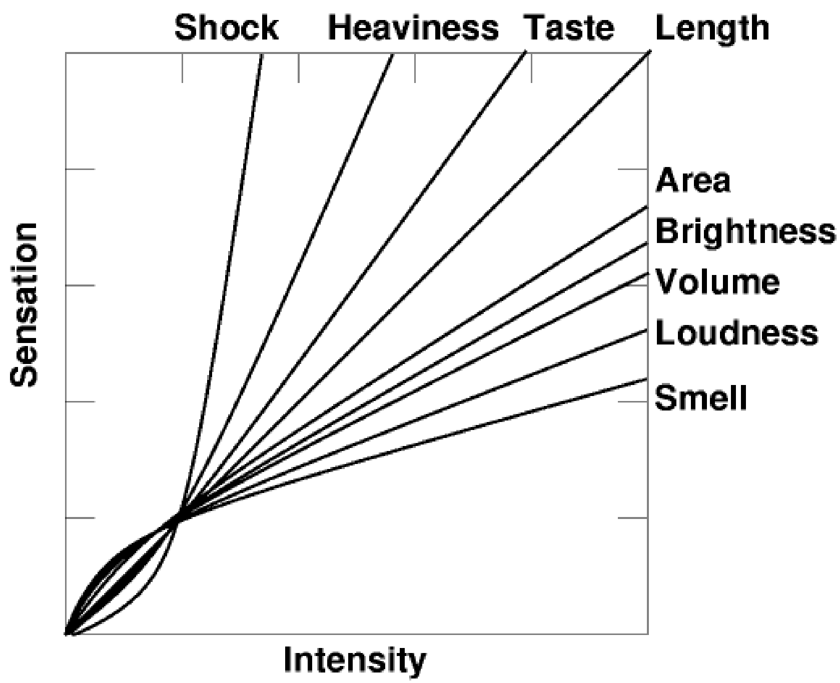


[graphics.stanford.edu/courses/cs448b-02-spring/lectures/encoding/walk015.html]

Nonlinear Perception of Magnitudes

sensory channels not equally discriminable

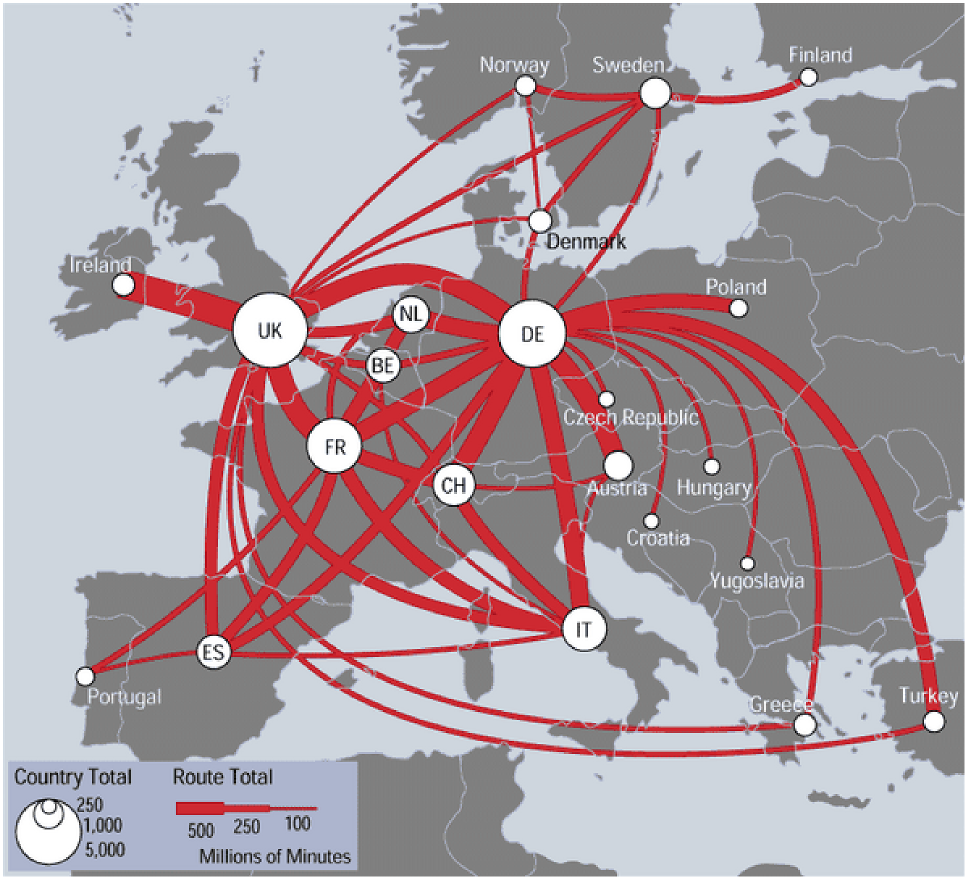
Stevens' Power Law: $I = S^p$



[Stevens, On the Theory of Scales of Measurement, Science 103:2684, 1946]

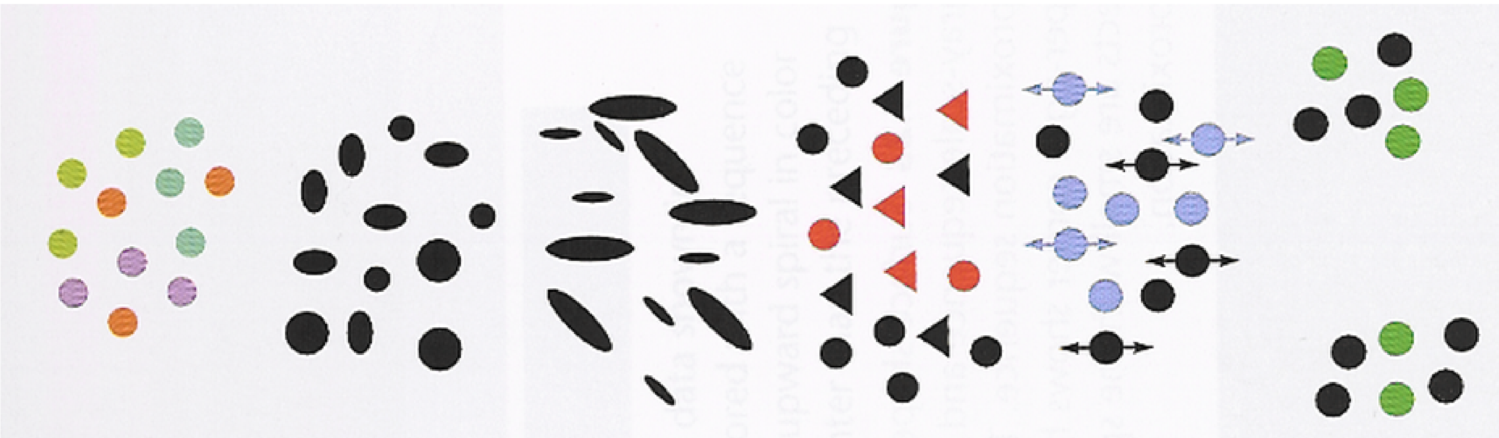
Channel Dynamic Range

linewidth: limited discriminability, but useful



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

Integral vs. Separable Channels

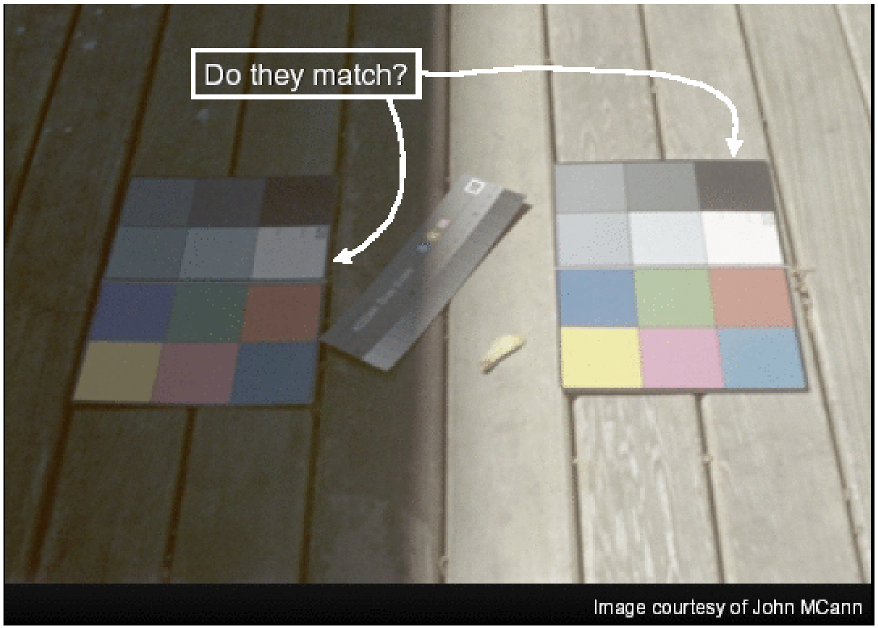


red-green yellow-blue | x-size y-size | size orientation | color shape | color motion | color location

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

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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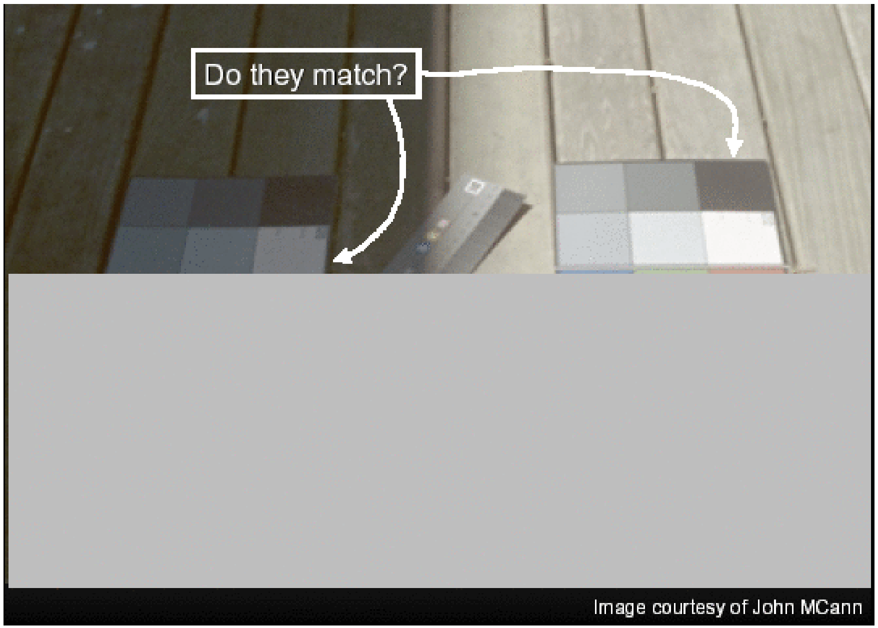

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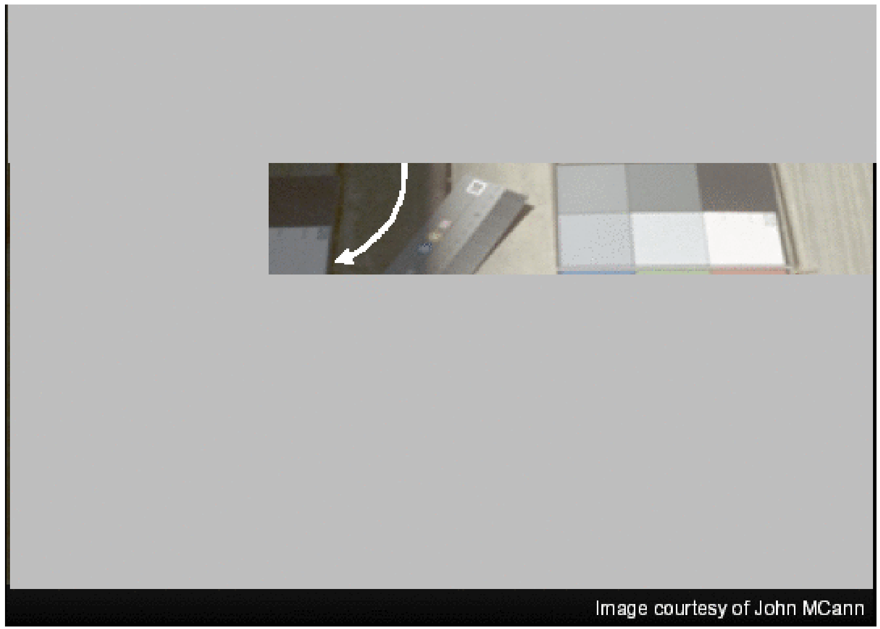

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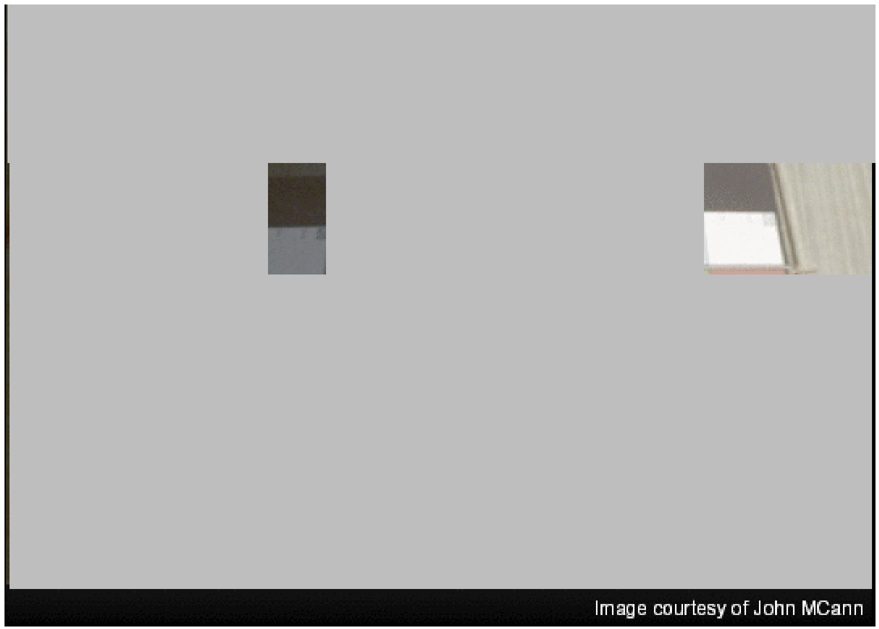

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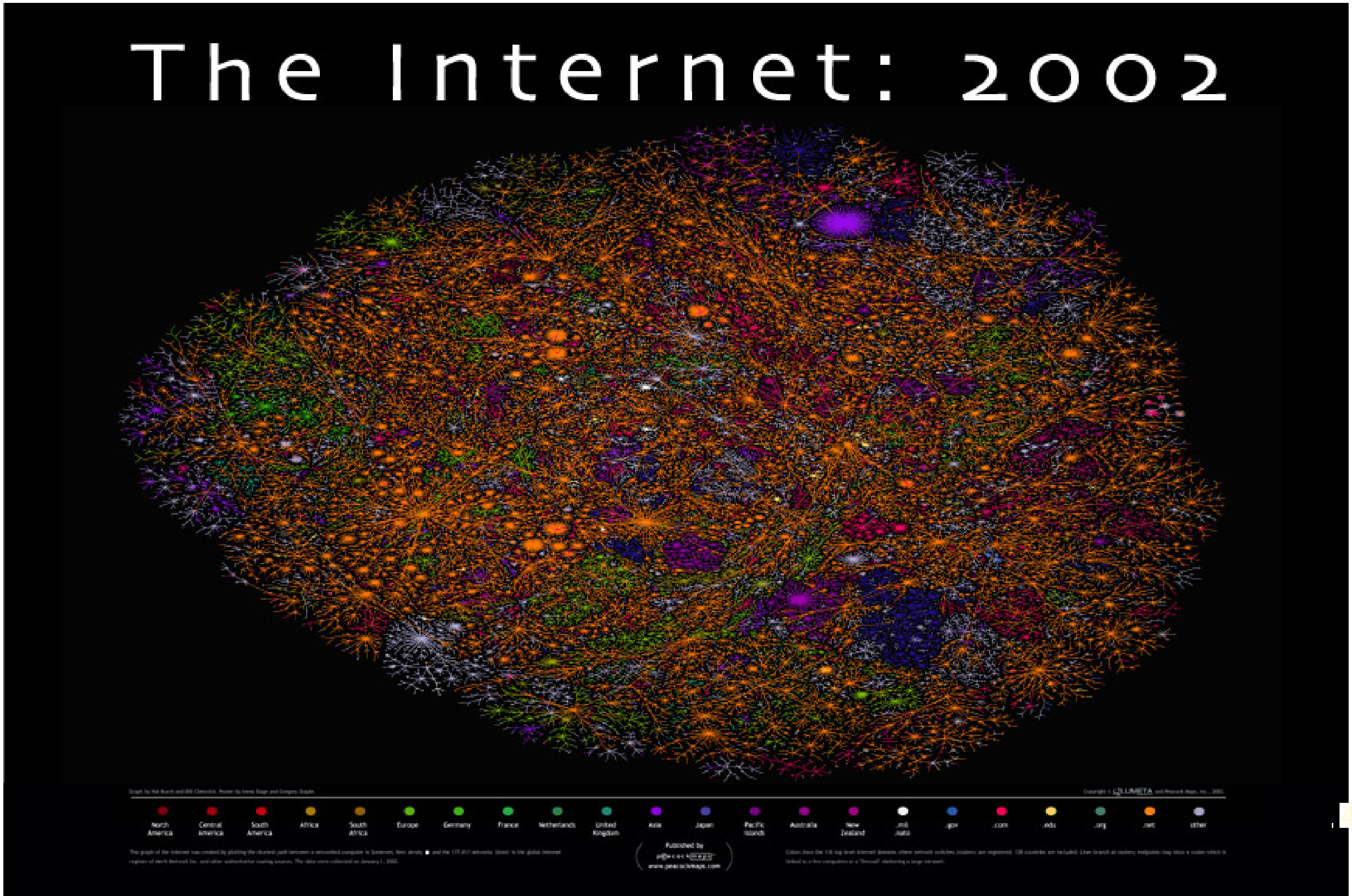
More Information

Coloring Categorical Data

22 colors, but only ~8 distinguishable 

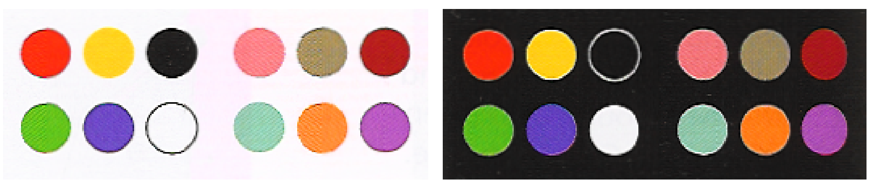


Coloring Categorical Data

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

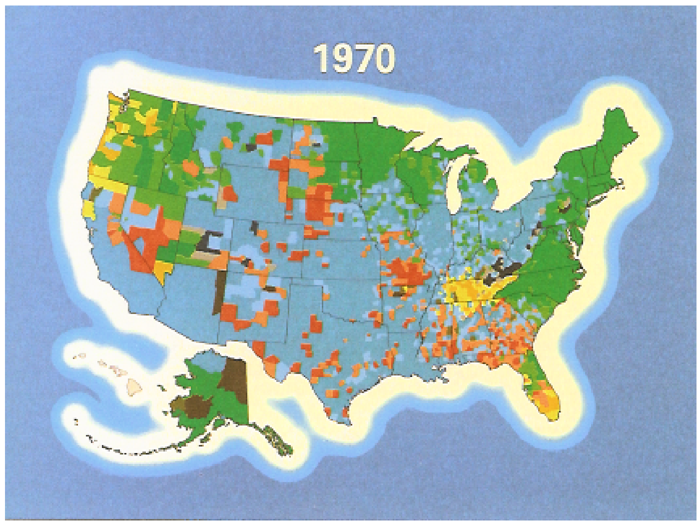


[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999. Figure 4.21]

Minimal Saturation for Large Areas

avoid saturated color in large areas

- "excessively exuberant"

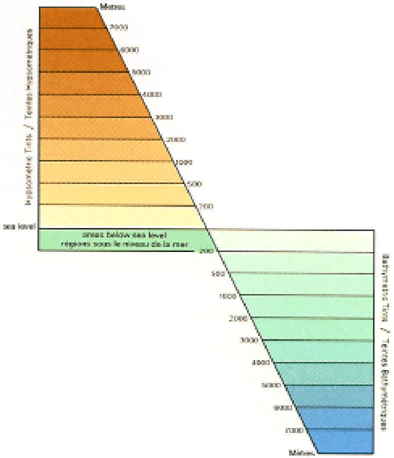


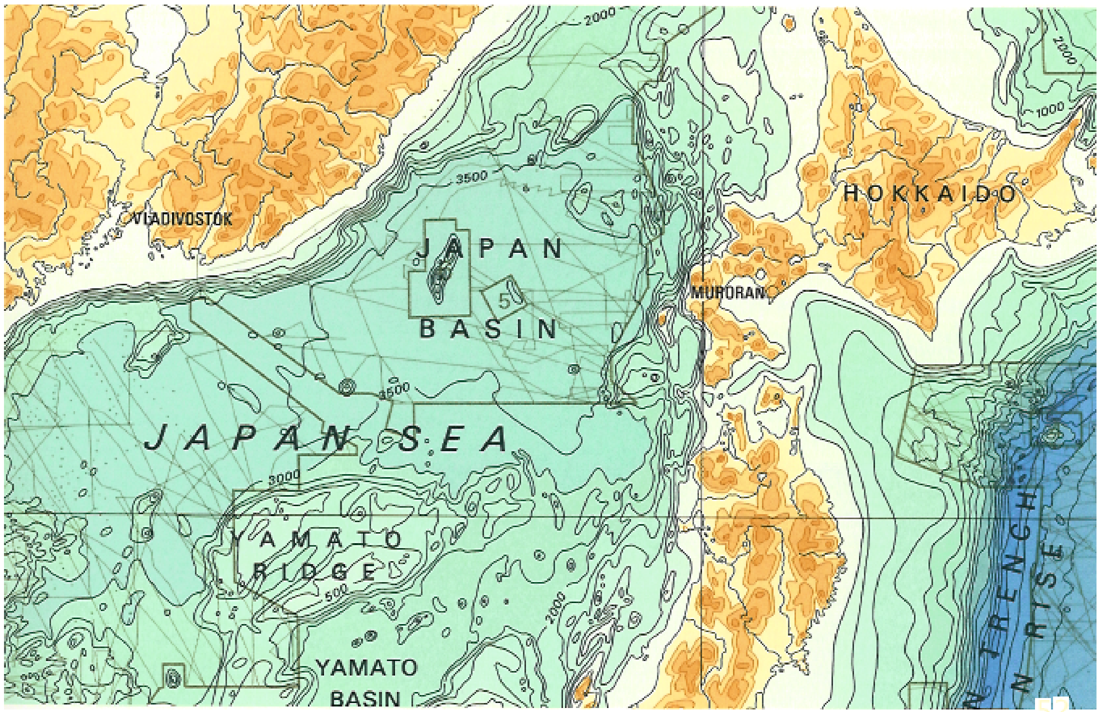
[Edward Tufte, Envisioning Information, p.82]

Minimal Saturation for Large Areas

large continuous areas in pastel

- diverging colormap (bathymetric/hypsometric)



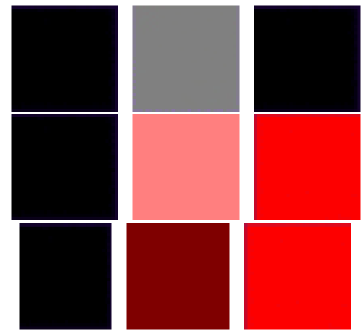


[Tufte, Envisioning Information, p. 91]

Coloring Ordered Data

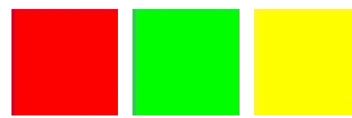
innate visual order

- greyscale/luminance
- saturation
- brightness



debatable visual order

- hue



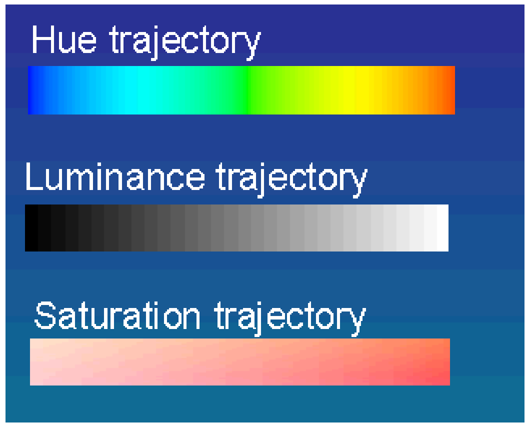
Coloring Quantitative Data

continuous field

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

mediocre
- hue (rainbow)

good
- greyscale/luminance
- saturation
- brightness

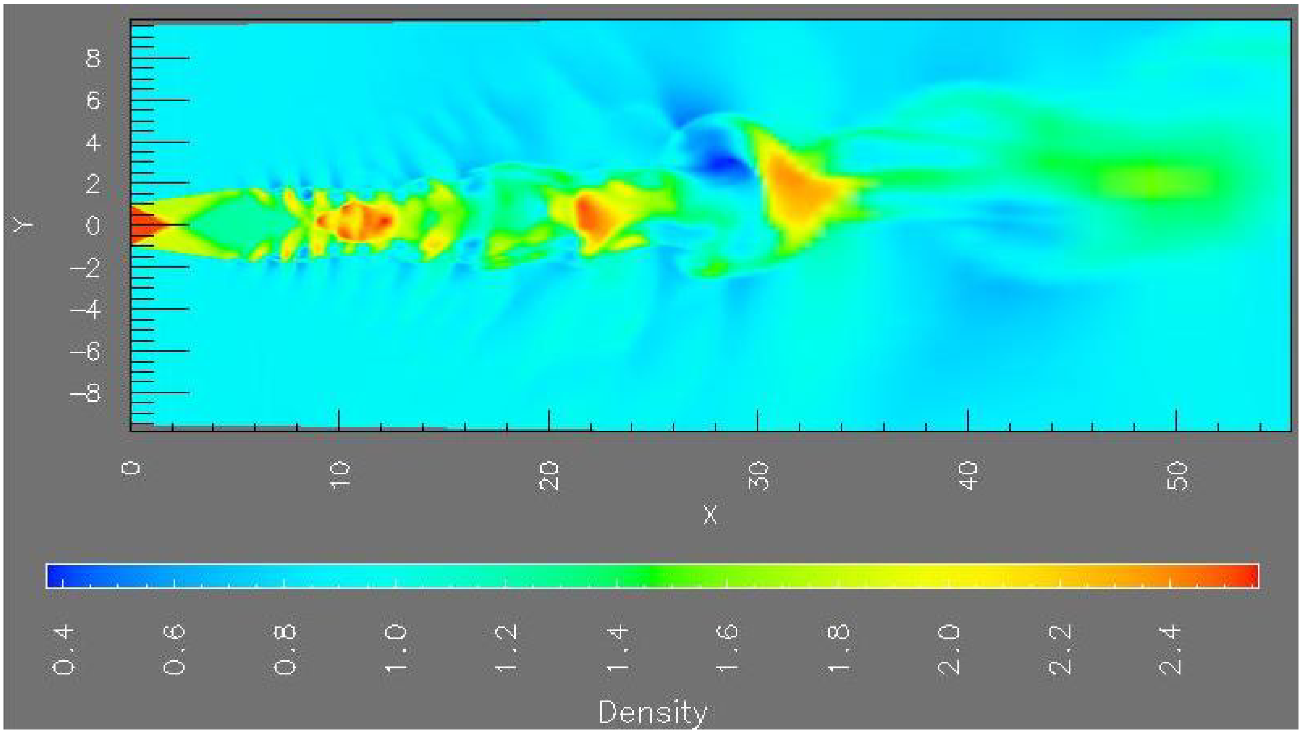


[www.research.ibm.com/visualanalysis/perception.html]

Rainbow Colormap Advantages

low-frequency segmentation

- "the red part", "the orange part", "the green part"

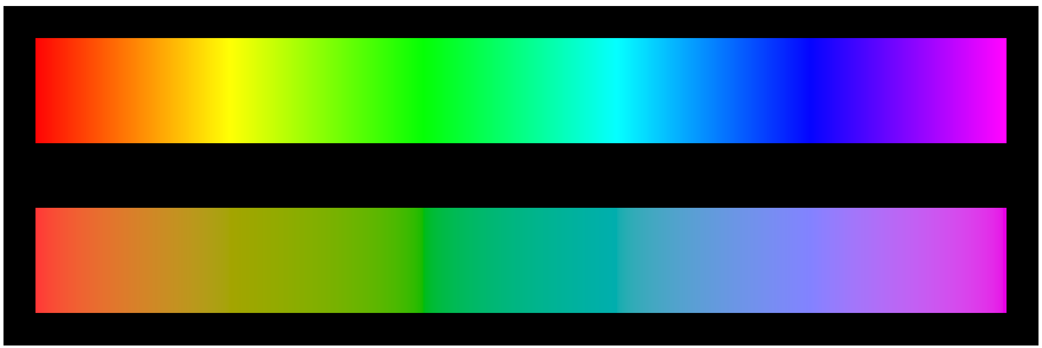


[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color?
http://www.research.ibm.com/people/l/lloydt/color/color.HTM

Rainbow Colormap Disadvantages

segmentation artifacts
- popular interpolation perceptually nonlinear!

solution
- create perceptually isolinear map

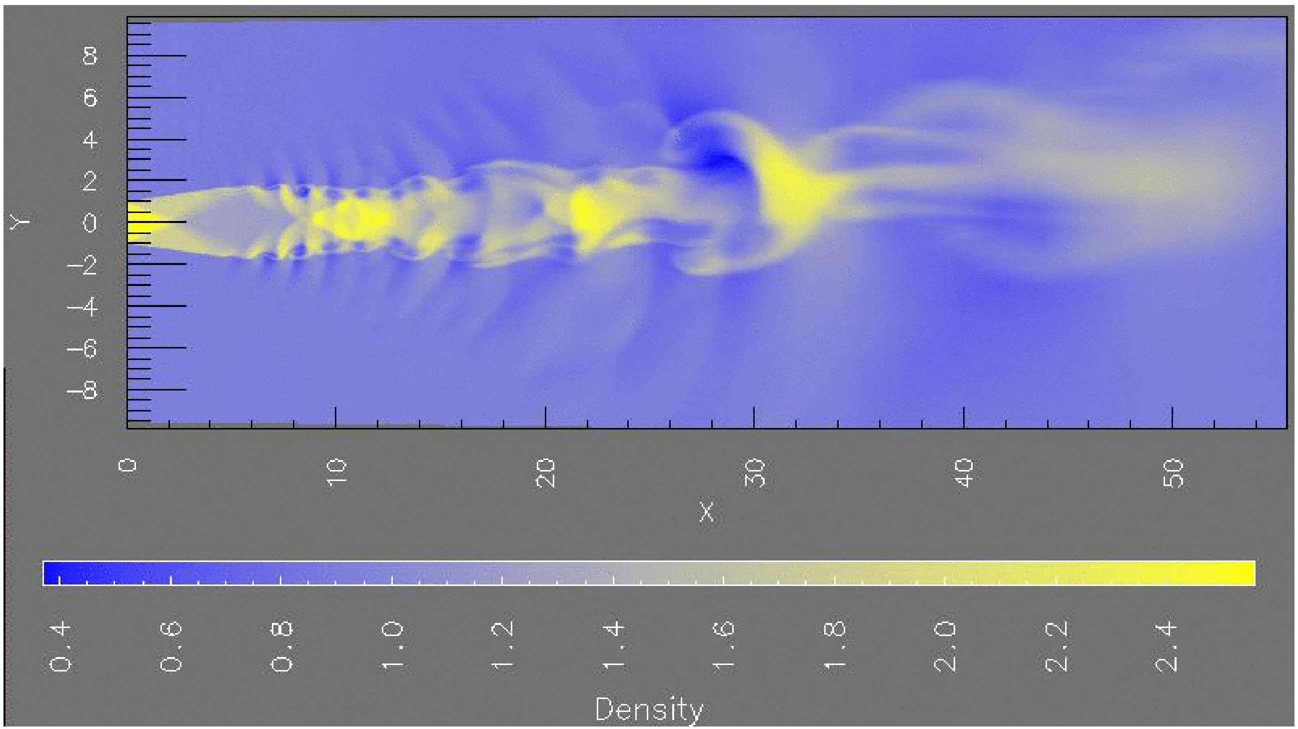


[Kindlmann, Reinhard, and Creem.
Face-based Luminance Matching for Perceptual Colormap Generation. Proc. Vis 02
www.cs.utah.edu/~gk/lumFace]

Non-Rainbow Colormap Advantages

high-frequency continuity

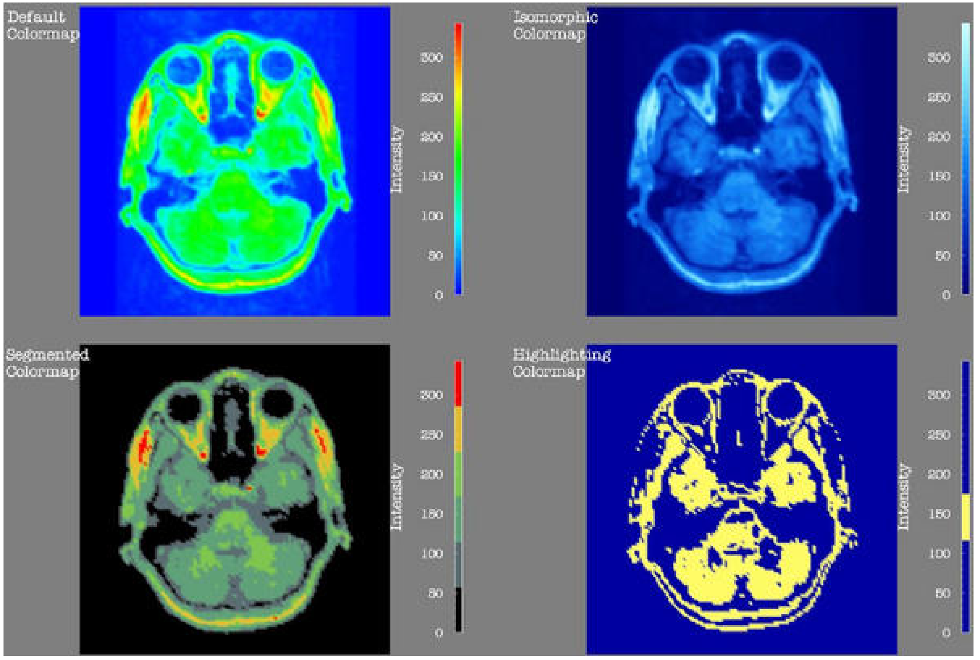
- interpolating between just two hues



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

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

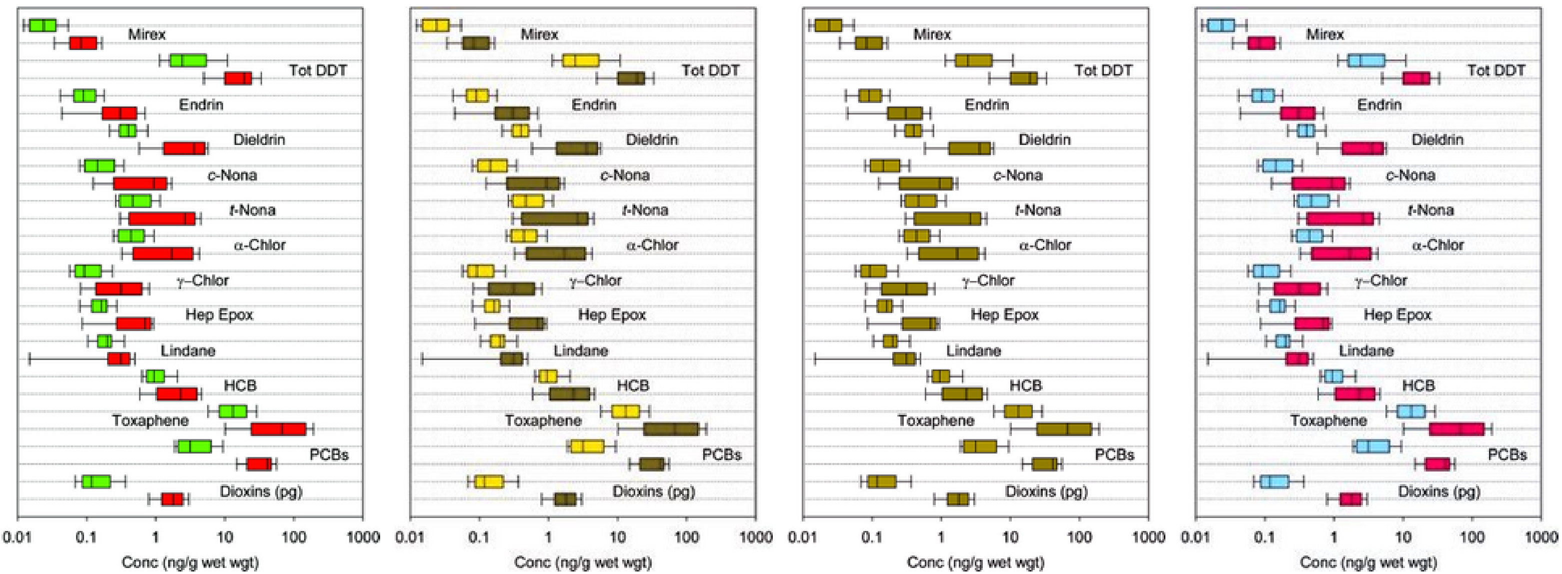
- has yellow/blue deficit

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.]

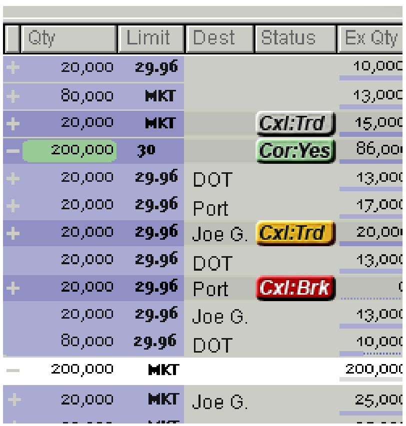
Designing Around Deficiencies

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]

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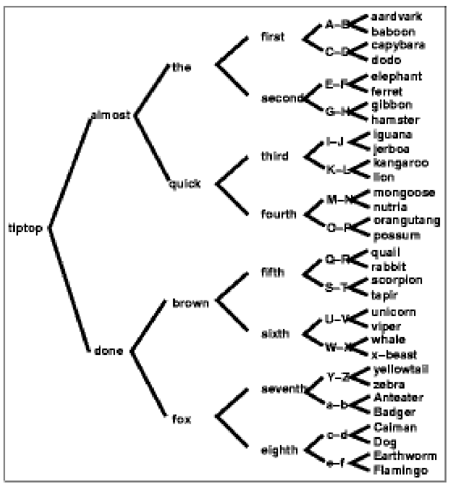
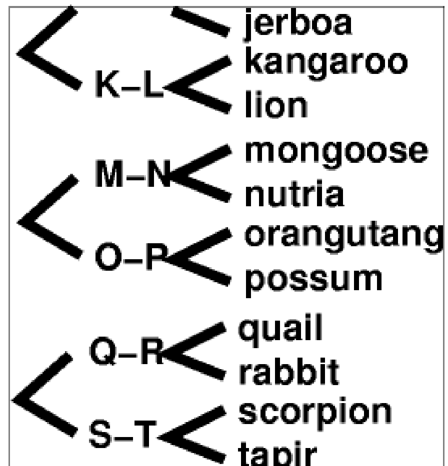
Overview+Detail

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

bad: one window, must remember position



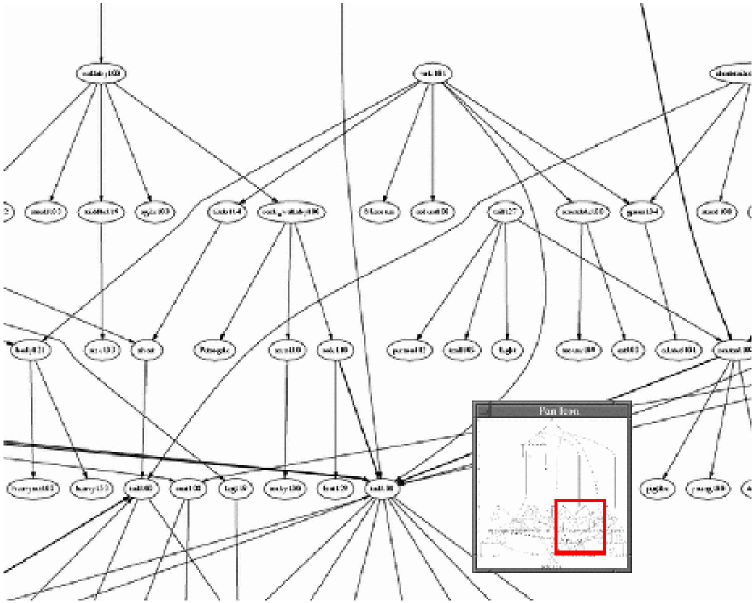
global overview



local detail

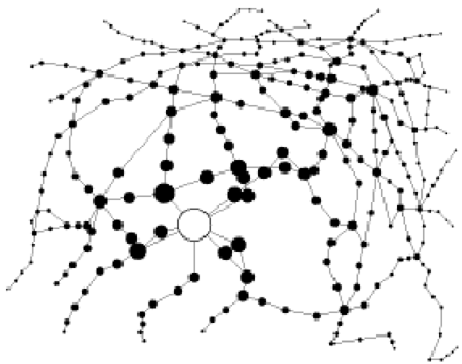
Overview+Detail

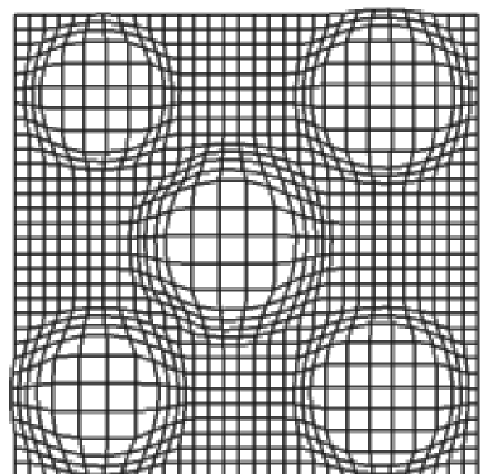
better: add linked overview window(s)
problem: still cognitive load to correlate



Focus+Context

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





[Manojit Sarkar and Marc H. Brown. Graphical Fisheye Views, CACM 37(12):73-84, Dec 199]
[Alan Keahey. www.cs.indiana.edu/~tkeahey/research/nlm/nlm.html]

Focus+Context: H3

3D fisheye (hyperbolic space)

- [demo]

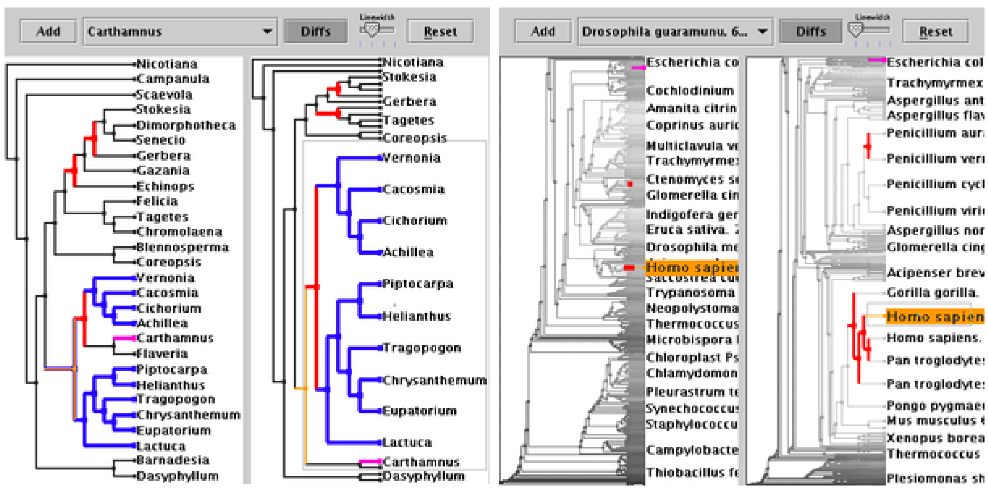
[Tamara Munzner. H3: Laying Out Large Directed Graphs in 3D Hyperbolic Space. Proc. InfoVis 1997. graphics.stanford.edu/papers/h3]

Focus+Context: TreeJuxtaposer

stretch and squish "rubber sheet"

guaranteed visibility

- keeping highlighted marks visible at all times
- [demo]



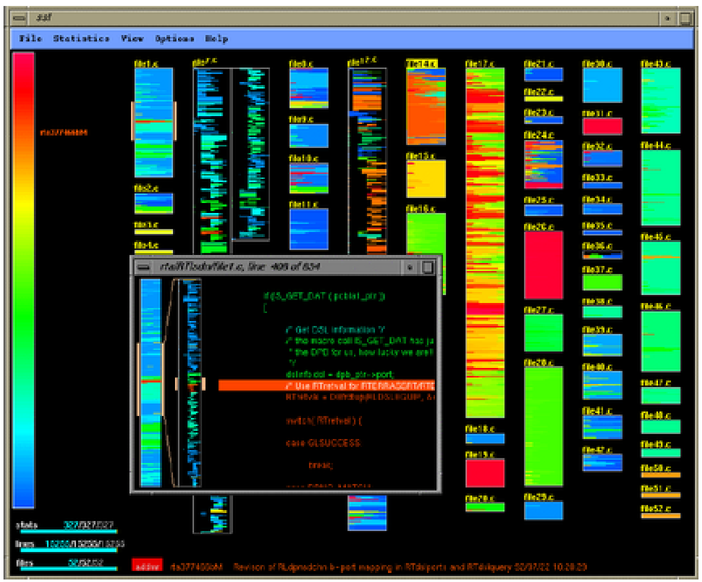
[TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility. Munzner et al. SIGGRAPH 2003. www.cs.ubc.ca/~tmm/papers/tj]

Constructing Overviews

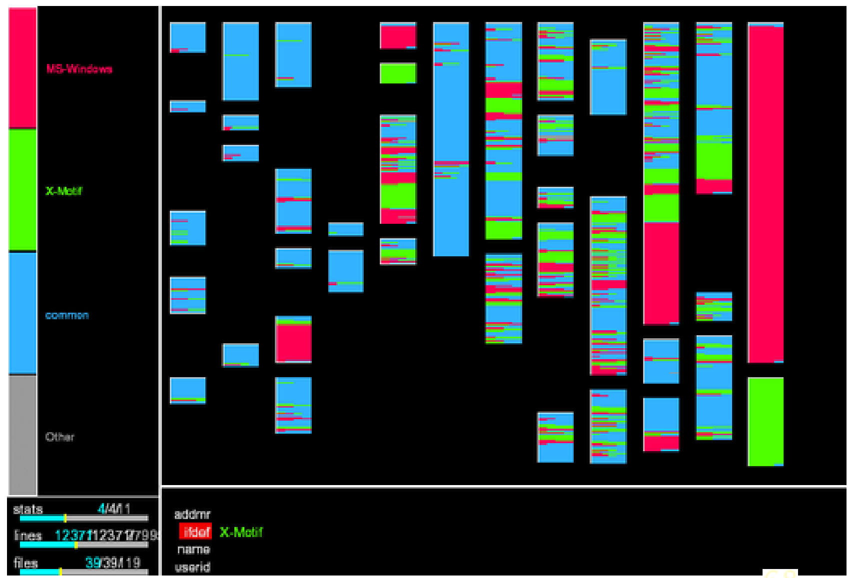
SeeSoft: software maintenance

- (colormaps: segmented vs. continuous)

code age



platform dependencies

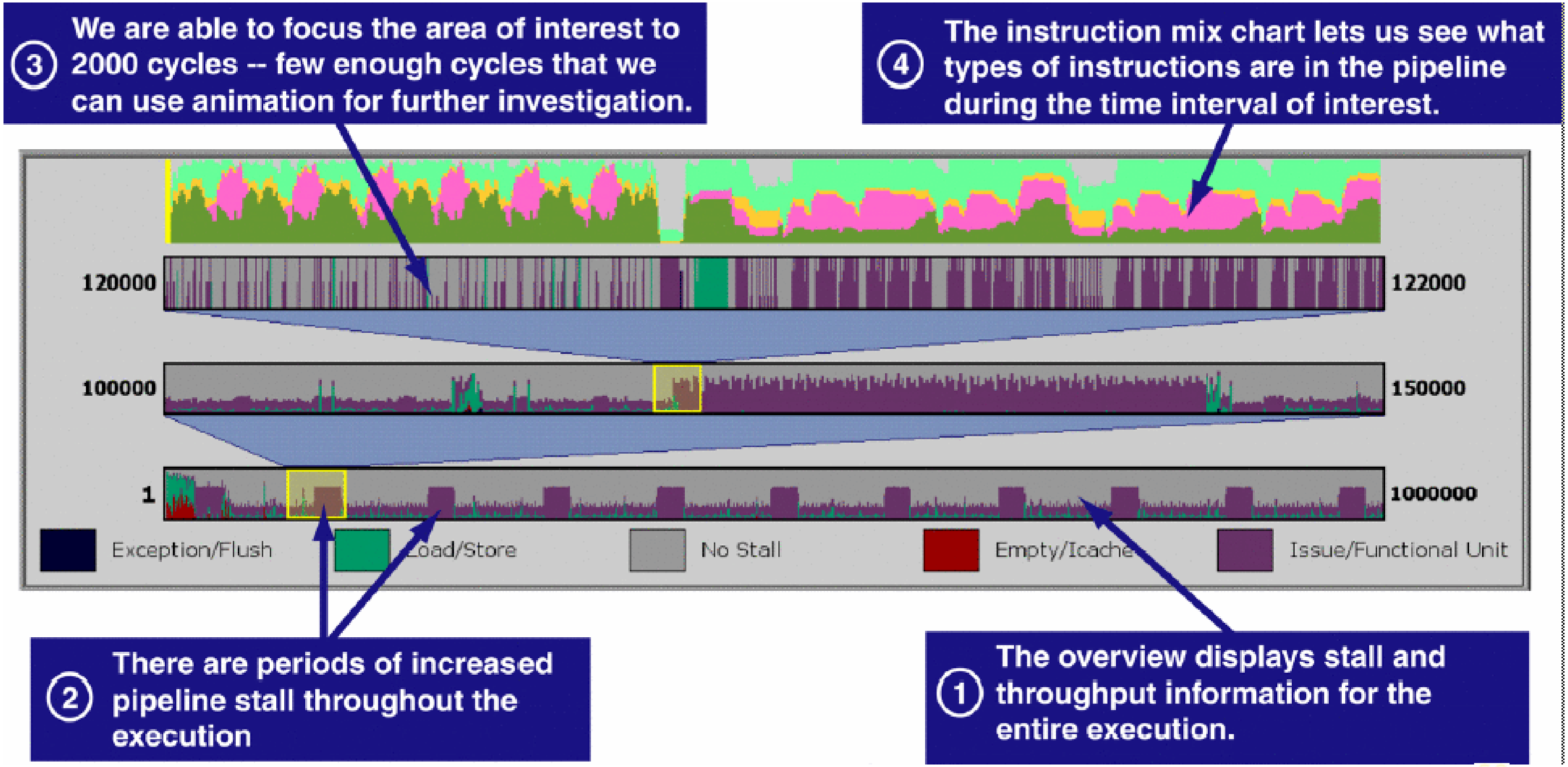


[Ball and Eick, Software Visualization in the Large, Computer 29:4, 1996
citeseer.nj.nec.com/ball96software.html]

Constructing Overviews

Rivet: performance tuning

- level of detail



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

Outline

Information Visualization Motivation

Designing for Humans

Information Visualization Techniques

- Using Color
- Overviews
- Space and Time
- Layering, Minimizing Occlusion

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

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 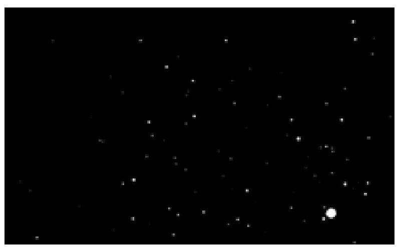 

[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]
[www.astroshow.com/ccdpho/pluto.gif]

Space vs. Time: Showing Change

literal abstract

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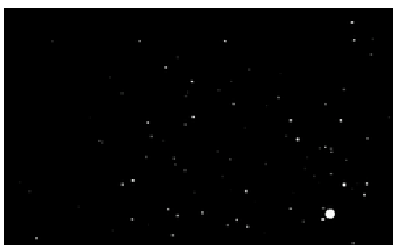
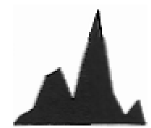
time for time space for time

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 abstract

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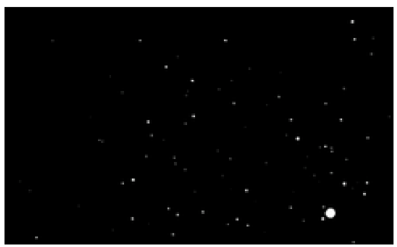
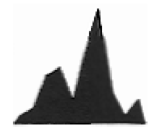
time for time space for time

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 abstract

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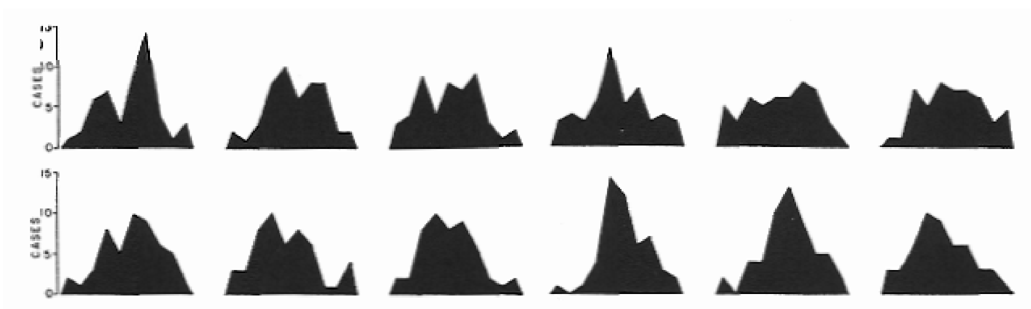
time for time space for time

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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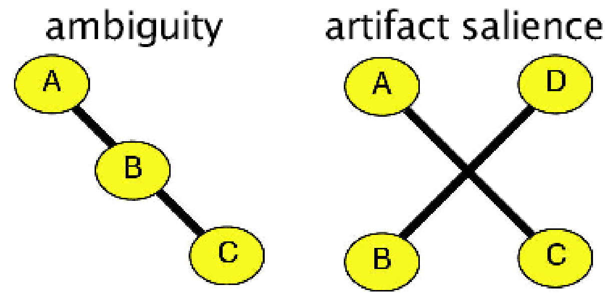
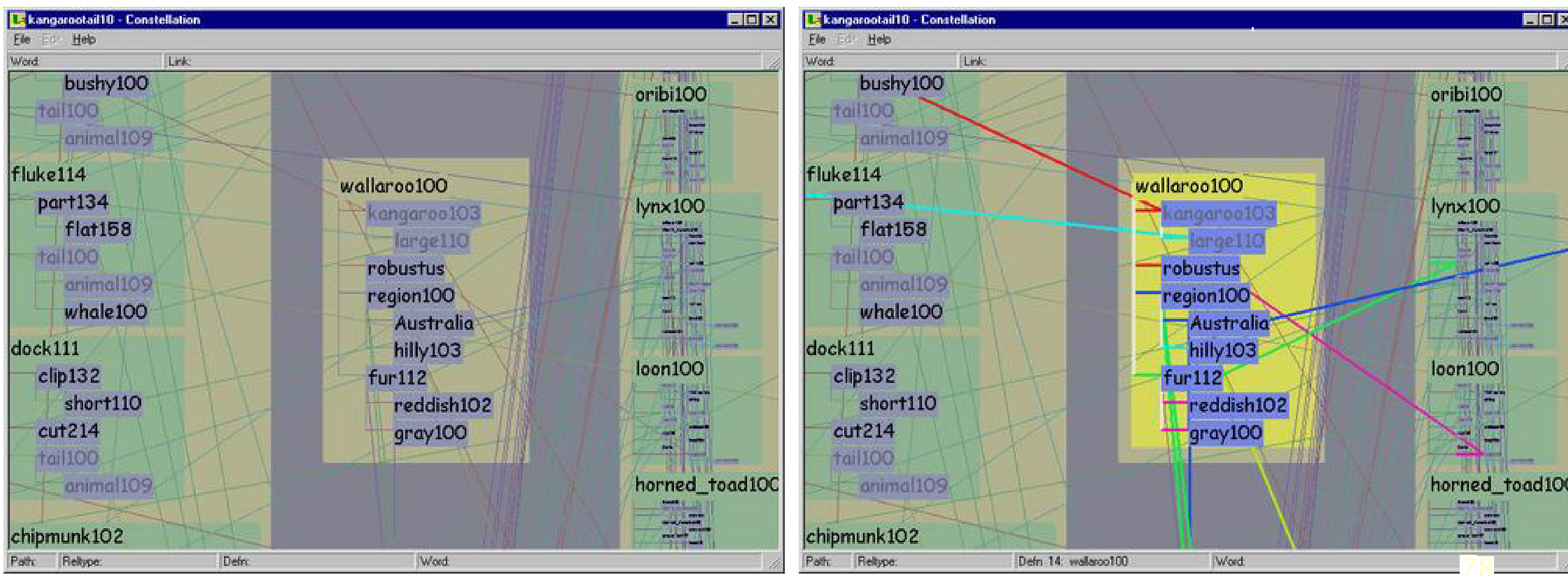
Layering: Cartography

Layering: Graphs

- edge crossing problem
  - false attachments
- layers to avoid perception
  - vs. spatial position

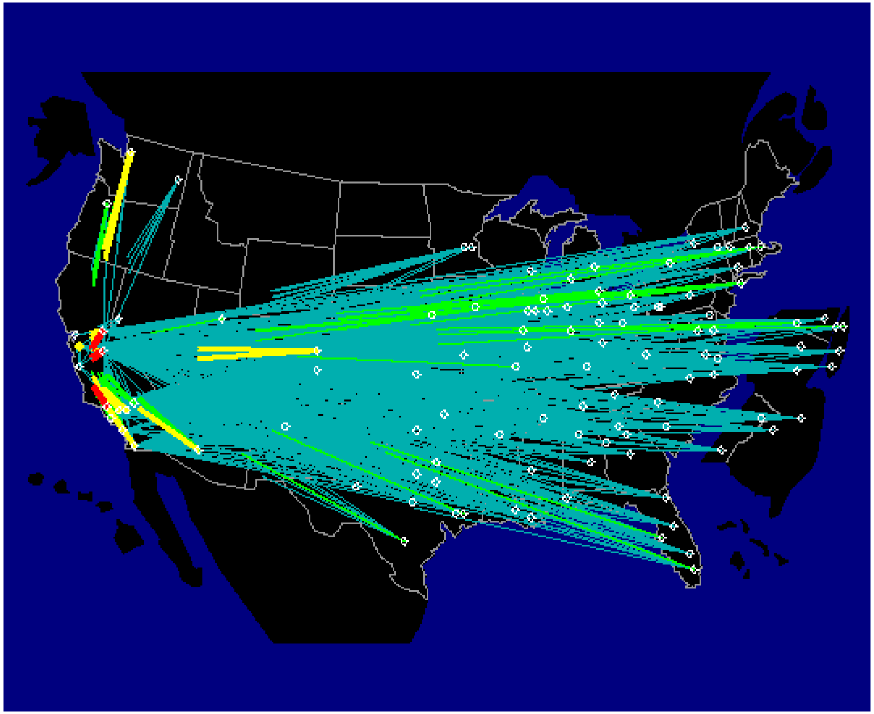




[Munzner et al, Constellation, Proc. InfoVis 99, graphics.stanford.edu/papers/const]

Minimizing Occlusion

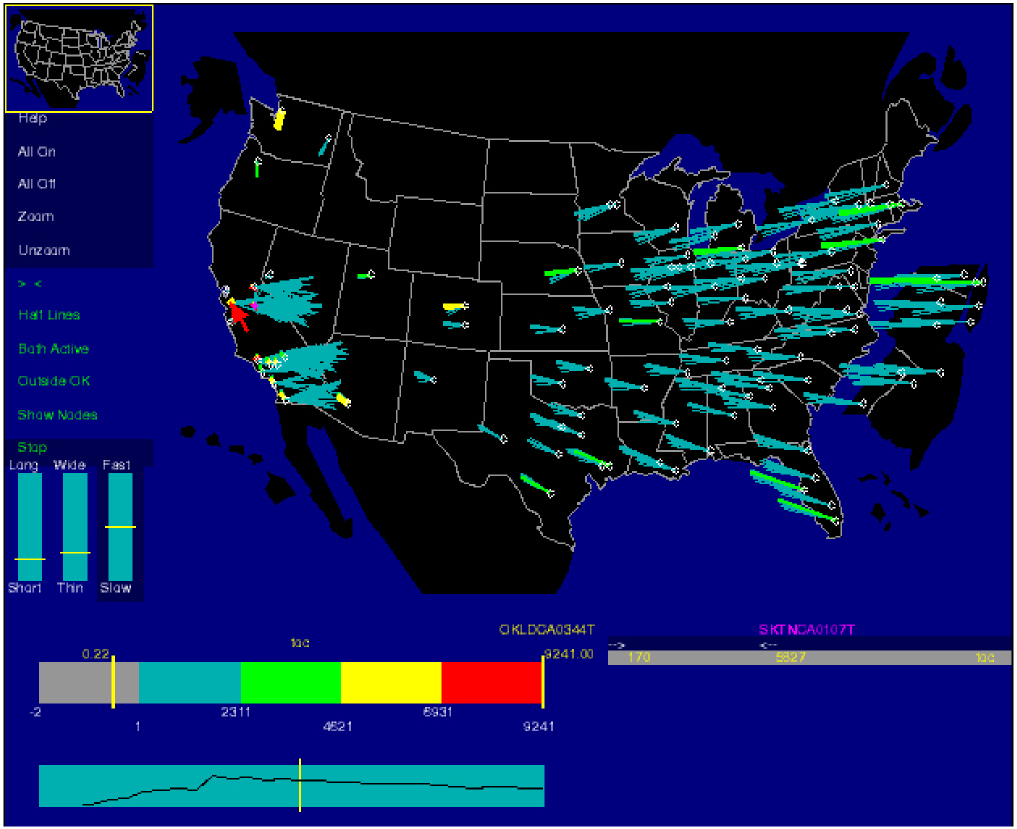
bad: Midwestern occlusion



[citeseer.nj.nec.com/becker95visualizing.html]
[Becker, Eick, and Wilks. Visualizing Network Data, IEEE TVCG 1995]

Minimizing Occlusion

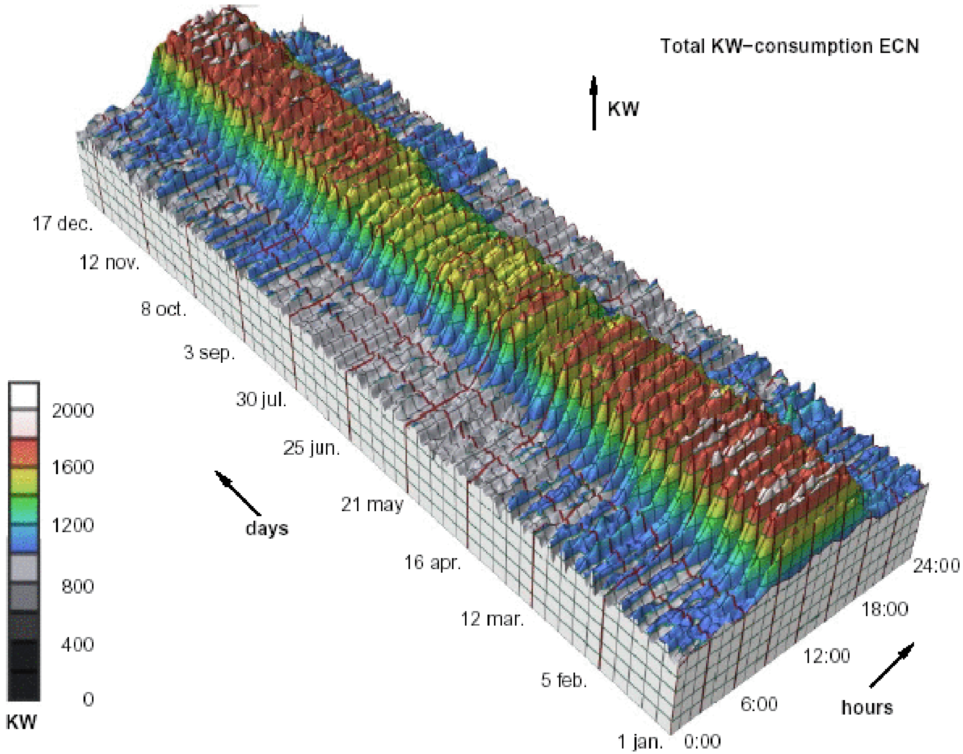
good: show only start and end of lines



[citeseer.nj.nec.com/becker95visualizing.html]
[Becker, Eick, and Wilks. Visualizing Network Data. IEEE TVCG 1995]

Minimizing Occlusion: 3D vs. 2D

bad: timeseries extrusion pretty but not useful

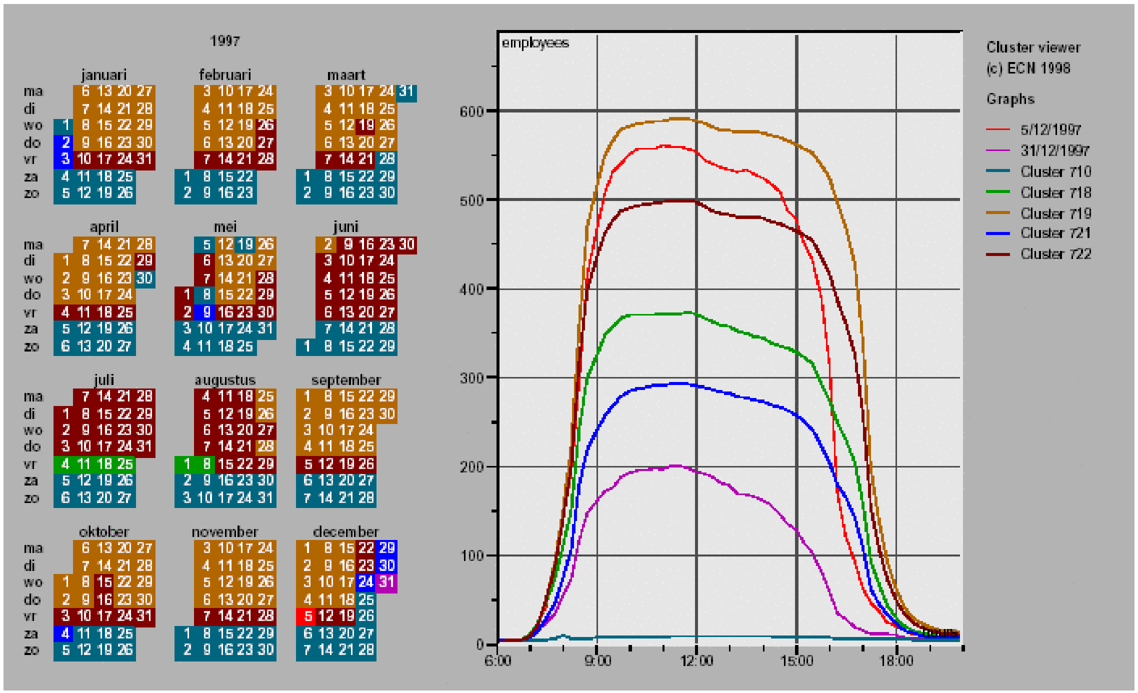


[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, Proc. InfoVis99, citeseer.nj.nec.com/vanwijk99cluster.html]

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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More Information

More Information

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, ...