Interactive Information Visualization

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Outline

information visualization motivation

designing for humans

information visualization techniques

future directions

Information visualization

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

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

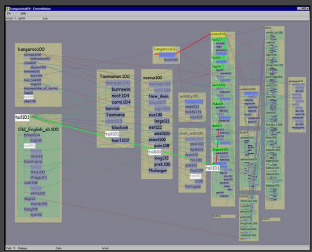
interactive visual representation of abstract data
- help human perform some task more effectively

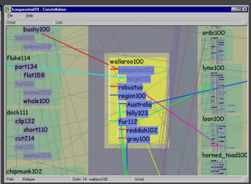
external representation
- reduces load on working memory

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

Task-oriented design

custom design for checking semantic networks
- reading definition subgraph labels

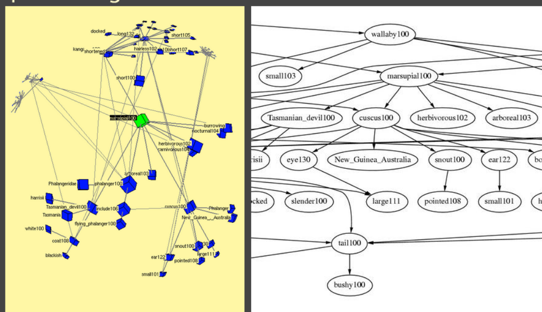




[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#layoutefffig]

Task-oriented design

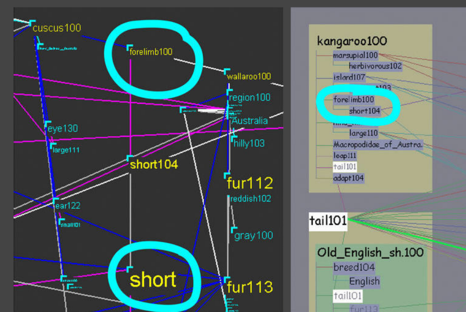
previous general methods



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

Design tradeoffs

information density vs. visual salience

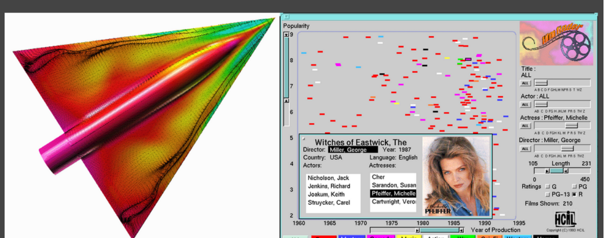


[graphics.stanford.edu/papers/munzner_thesis/html/node11.html#noncanonfig]

Scientific vs. information visualization

scivis: inherently spatial data
- fluid flow over airplane wing

infovis: abstract data, choice of spatialization
- FilmFinder



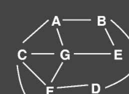
[www.nas.nasa.gov/NASnews/95/05/delta.html]

[Ahlberg and Shneiderman. CHI 94]

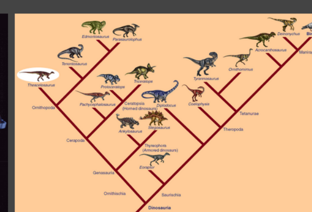
Example: node-link graphs

powerful abstraction

common in many domains



[Cox and Patterson 92]



[www.dinoheart.org/images/cladogram.gif]

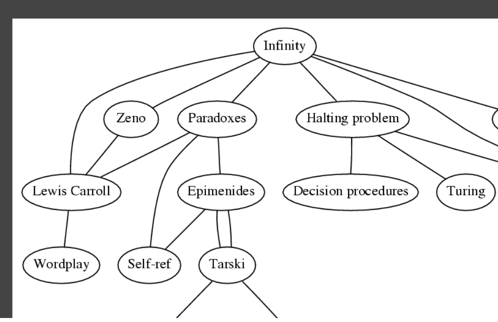
Why visualize graphs?

Example: book topic relationships
- [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
[...]

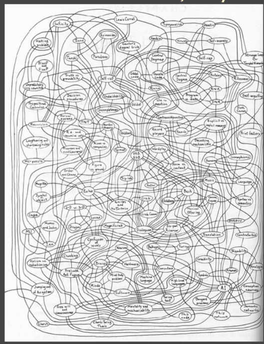
Why visualize graphs?

offload cognition to visual systems
minimal attention to read answer



Why draw graphs automatically?

manual: hours, days



[Godel, Escher, Bach. Hofstader 79]

automatic: seconds

dot, [Gansner et al 93]

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Human perception

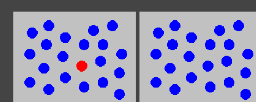
sensors/transducers
- psychophysics: determine characteristics

relative judgements: strong
absolute judgements: weak

different optimizations than most machines
- eyes are not cameras
- perceptual dimensions not nD array
- (brains are not hard disks)

Preattentive visual dimensions

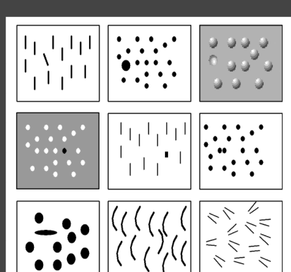
color (hue) alone: preattentive
- attentional system not invoked
- search speed independent of distractor count



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

Preattentive visual dimensions

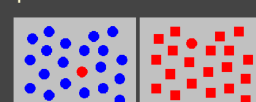
many preattentive dimensions of visual modality
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction



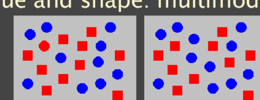
[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive visual dimensions

color alone: preattentive
shape alone: preattentive



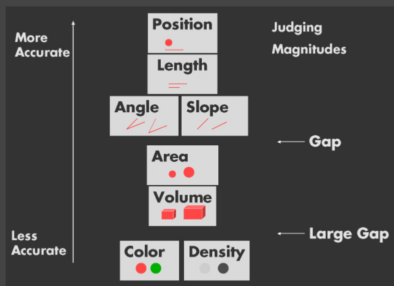
combined hue and shape: multimodal



- requires attention
- search speed linear with distractor count

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

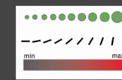
Dimensional ranking



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

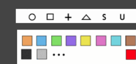
Data types

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



ordered (ordinal)
- small, medium, large

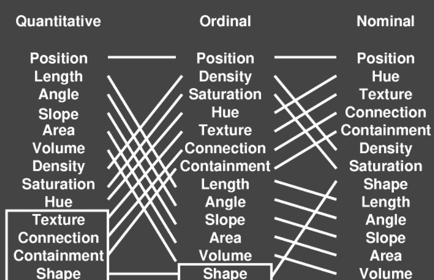
categorical (nominal)
- apples, oranges, bananas



[graphics.stanford.edu/papers/polaris]

Dimensional ranking varies by data type

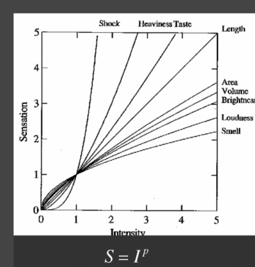
spatial position best for all types



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

Nonlinear perception of magnitudes

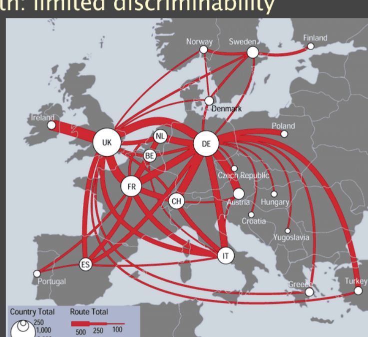
sensory dimensions not equally discriminable
- Stevens power law



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

Dimensional dynamic range

linewidth: limited discriminability



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

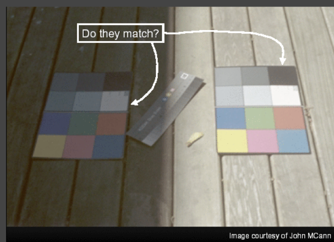
Integral vs. separable dimensions

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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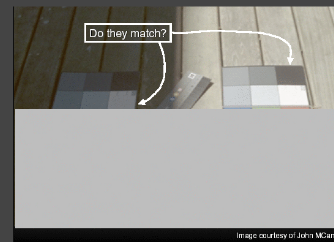

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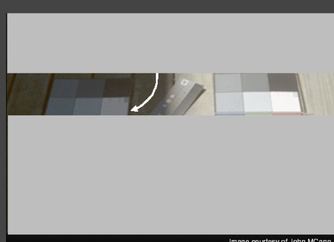

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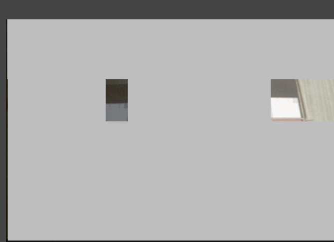

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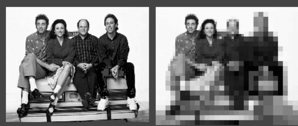
Color/Brightness Constancy

segmentation: relative judgements

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

Foveal Vision

thumbnail at arm's length
small high resolution area on retina



[www.cs.nyu.edu/~yap/visual/home/proj/foveation.html
svi.cps.utexas.edu/examples_foveated.html]

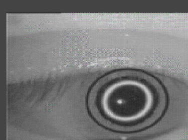
Equal Legibility

if fixated on center point

[psy.ucsd.edu/~sanstis/SABlur.html]

Eyes

saccades
- fovea: high-resolution samples
- brain makes collage
- vision perceived as entire simultaneous field
- fixation points: dwell 200-600ms
- moving: 20-100ms



[vision.arc.nasa.gov/personnel/jbm/home/projects/osa98/osa98.html/

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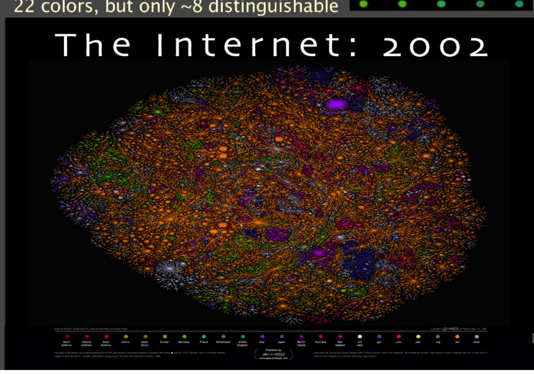
Coloring Categorical Data

22 colors, but only ~8 distinguishable 



Coloring Categorical Data

discrete small patches separated in space

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

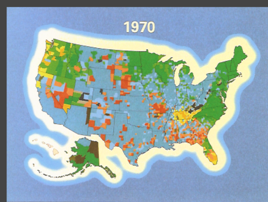
maximally discriminable colors from Ware
- maximal saturation for small areas

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

choose bins explicitly for maximum milage

Minimal Saturation for Large Areas

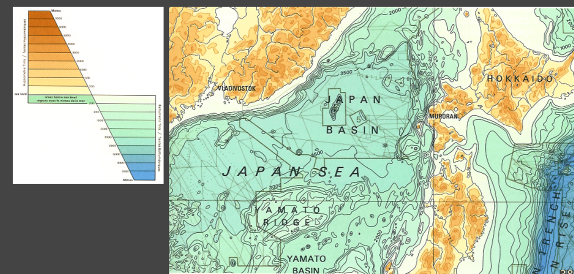
avoid saturated color in large areas
- "excessively exuberant"



[Edward Tufte, Envisioning Information, p.82]

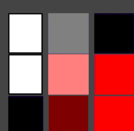
Minimal Saturation for Large Areas

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



Coloring Ordered Data

innate visual order
- greyscale/luminance
- saturation
- brightness



unclear visual order
- hue

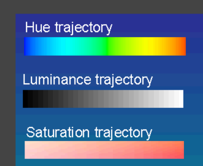
Coloring Quantitative Data

continuous field

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

mediocre
- hue (rainbow)

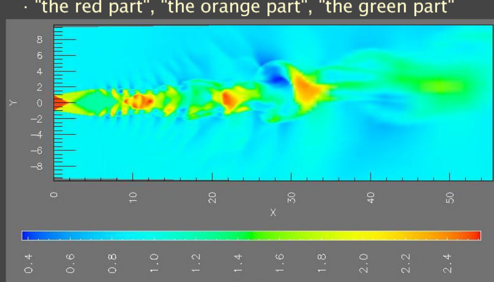
good
- greyscale/luminance
- saturation
- brightness



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

Rainbow Colormap Advantages

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

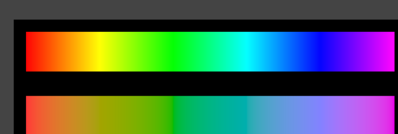


[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color?
http://www.research.ibm.com/people/l/lloydt/color/color.HTM

Rainbow Colormap Disadvantages

segmentation artifacts
- popular interpolation perceptually nonlinear!

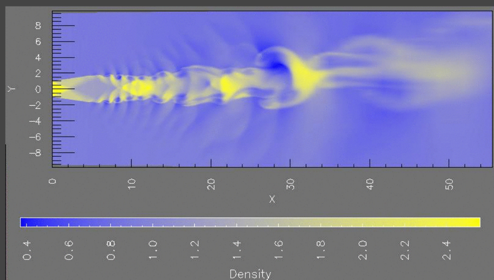
solution
- create perceptually isolinear map



[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

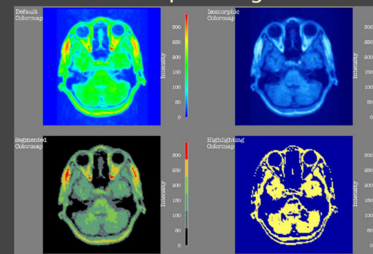
high-frequency continuity
- interpolating between just two hues



[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!

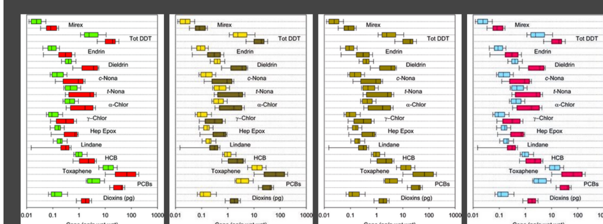
protanope
deutanope
- has red/green deficit
- 10% of males!

tritanope
- has yellow/blue deficit

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

Color Deficiency Examples: vischeck

original protanope deuteranope tritanope

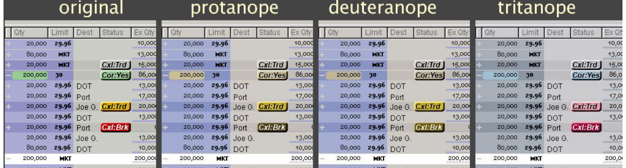


[www.cs.ubc.ca/~tmm/courses/cpsc533c-04-spr/a1/dmitry/533a1.html,
citing Global Assessment of Organic Contaminants in Farmed Salmon,
Ronald A. Hites, Jeffery A. Foran, David O. Carpenter, M. Coreen
Hamilton, Barbara A. Knuth, and Steven J. Schwager, Science 2004 303: 226-229.]

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

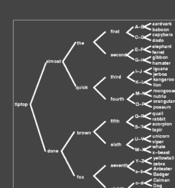


[Courtesy of Brad Paley]

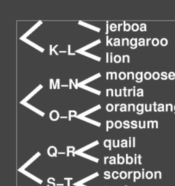
Overview+detail

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

bad: one window, must remember position



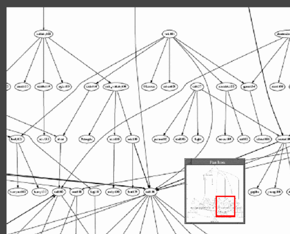
global overview



local detail

Overview and detail

better: add linked overview window(s)



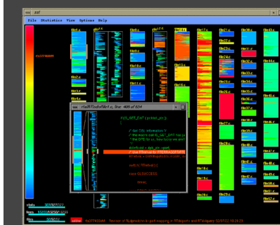
how to create overview?

Overview and detail

SeeSoft: software maintenance

- (colormaps: segmented vs. continuous)

code age



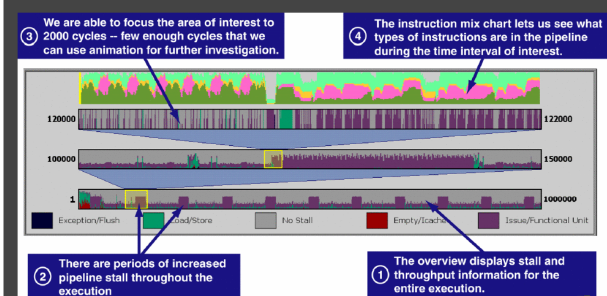
platform dependencies

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

Overview+detail

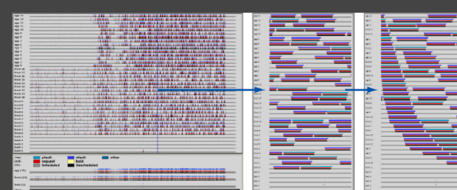
Rivet: performance tuning

- level of detail



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

Overview to detail to sorting



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

Focus+context

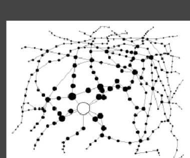
linked windows

- still have cognitive load to correlate

good solution:

- merge overview, detail into single window

fisheye views [Furnas 86], [Sarkar et al 94]



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good solution:

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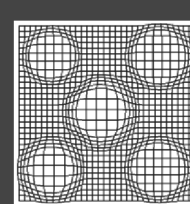
fisheye views [Furnas 86], [Sarkar et al 94]
nonlinear magnification [Keahey 96]



Focus+context

H3 [Munzner 97]

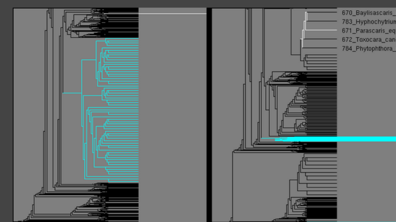
- task: browsing large quasi-hierarchical graphs
- [demo]

[Munzner 1997, 1998a, 1998b]

Global focus+context

TreeJuxtaposer: comparing trees

- linked highlighting
- [demo]



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

<--->

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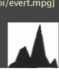
- good: show process
- good: compare by flipping between two things
- bad: compare between many things

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



Space vs. Time: Showing Change

literal — abstract

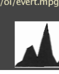
<--->

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
  interference from intermediate frames

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

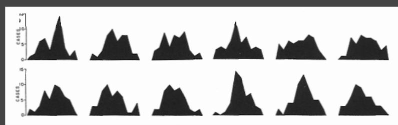


Space vs. Time: Showing Change

literal <------------------------------------> abstract

time for time — space for time

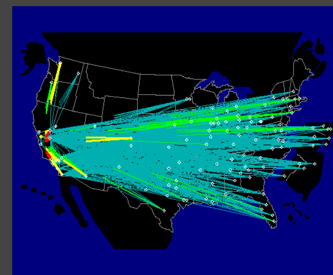
small multiples: show time using space
- overview: show each time step in array
- compare: side-by-side easier than temporal
  - external cognition instead of internal memory
- general technique, not just for temporal changes



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

Minimizing occlusion

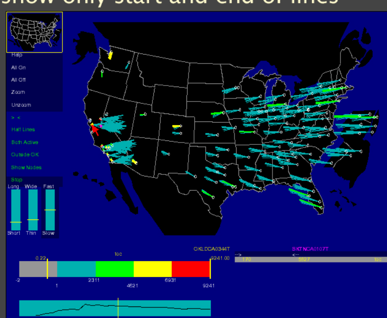
bad: Midwestern occlusion



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

Minimizing occlusion

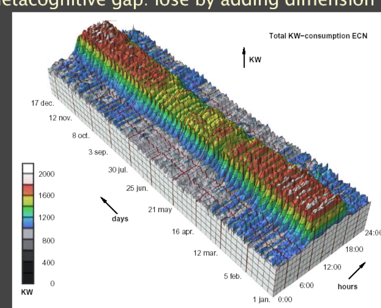
good: show only start and end of lines



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

Minimizing occlusion: 3D vs. 2D

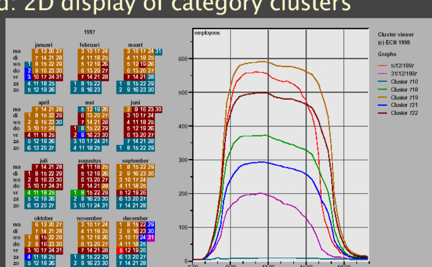
bad: 3D pretty but not useful
- metacognitive gap: lose by adding dimension



[van Wijk and van Selow, Cluster and Calender based Visualization of Time Series Data, InfoVis99,

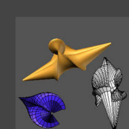
Minimizing occlusion: 3D vs. 2D

good: 2D display of category clusters



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

Motion: clarify structure



navigation
- rotate/translate/zoom

[www.psy.vanderbilt.edu/faculty/blake/biowalker.gif]

object recognition
- moving lights at joints
  - Johannson 1973

animated transitions
- avoid change blindness
  - jump increases cognitive load
- smooth transition from one state to next
  - maintain object constancy

Outline

information visualization motivation

designing for humans

information visualization techniques

future directions

Future: scaling to huge datasets

data explosion

- sensors
  - Human Genome Project
  - Sloan Digital Sky Survey
- simulation
  - Accelerated Strategic Computing Initiative
  - microprocessor design
- logging
  - long-distance telephony backbone
  - Web traffic

Future: dynamic data

static
- hyperlink structure of entire Web

dynamic
- entire Web changing through time (Internet Archive)

open problem: incremental/online layout

- minimal visual changes: maintain user's mental model
- faithfully represent current state

Future: scaling display resolution

always pixel-bound in past

high-res displays now available
- 4K x 2K: 9Mpixels vs 1 Mpixel
- pixel rich

interactivity + resolution of paper
- add physical navigation (walk closer) to virtual navigation

Project domains

current
- bioinformatics
- data mining
- environmental sustainability

past
- topology
- networking
- computational linguistics
- web site design

More Information

Term 1 course: 533C Visualization

email me to schedule time to talk
- tmm@cs.ubc.ca
- FSC 2618
  Term 1 office hours: 3:45-4:45 Wed

http://www.cs.ubc.ca/~tmm