Interactive Information Visualization

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UBC CPSC 414
Week 11, Wed 12 November 2003

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

Visualization Tasks

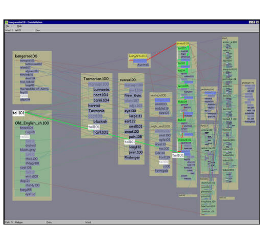
overview
zoom
filter
details-on-demand

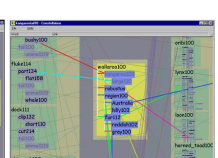
relate
history
extract

[The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations.
Ben Shneiderman
citeseer.nj.nec.com/shneiderman96eyes.html]

Task-oriented design

custom design for checking semantic networks
- reading definition subgraph labels

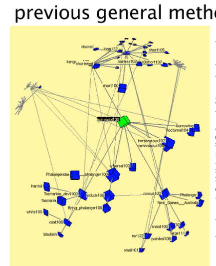


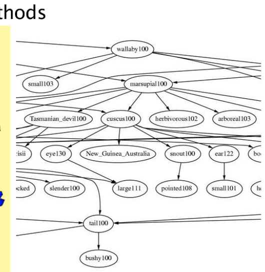


[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#layoutefffig]

Task-oriented design

previous general methods

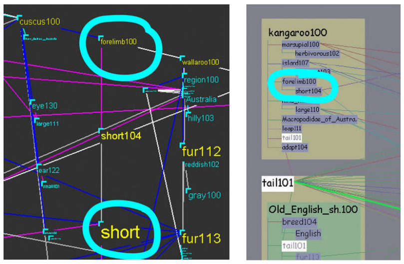




[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#dotconstfig]

Design tradeoffs

information density vs. visual salience



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

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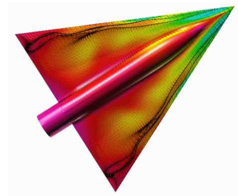
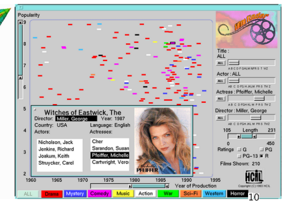
Scientific vs. information visualization

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]

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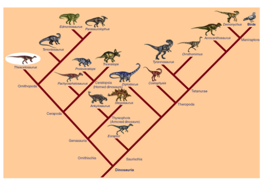
Example: node-link graphs

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
[...]

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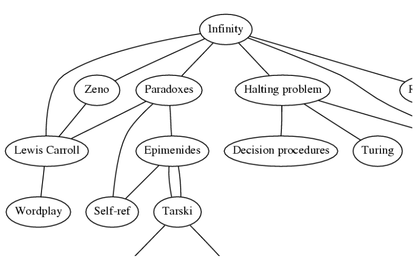
Why visualize graphs?

offload cognition to visual systems
minimal attention to read answer



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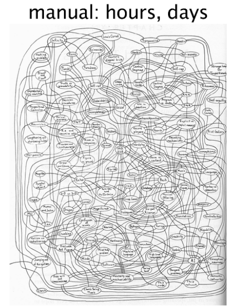
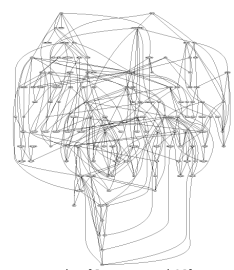
Why draw graphs automatically?

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)

limits of intuition
- thoughts, goals, plans: accurate
- vision, hearing, attention, memory: inaccurate

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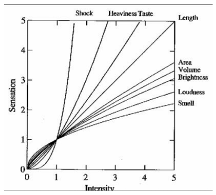
Nonlinear perception of magnitudes

sensory dimensions not equally discriminable

- JND: Just Noticeable Differences
- Stevens power law



S = I^p

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

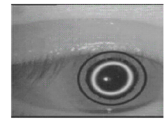
Eyes

foveal vision

- high resolution
- thumbnail at arm's length

saccades [video]

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

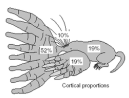


[vision.arc.nasa.gov/personnel/jbm/home/projects/osa98/osa98.html/

Fovea

low-res periphery, high-res sensor

- general concept, not just for eyes
- foveal touch!: star-nosed mole

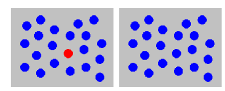



[www.nature.com/nsu/010329/010329-6.html
brain.nips.ac.jp/event/work131030/Catania_and_Kaas,_1997.pdf]

Preattentive visual dimensions

color (hue) alone: preattentive

- attentional system not invoked
- search speed independent of distractor count

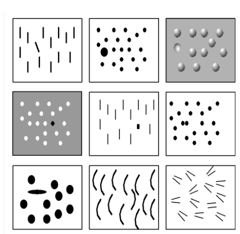


[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive visual dimensions

many preattentive dimensions of visual modality

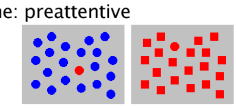
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction



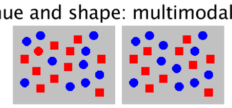
[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP/PP.html]

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]

Well, actually...

sometimes works (motion + color)

but need both preattentive and cognitive

- for, say, designing visualizations

Integral vs. separable dimensions

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

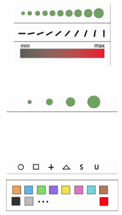
[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

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]

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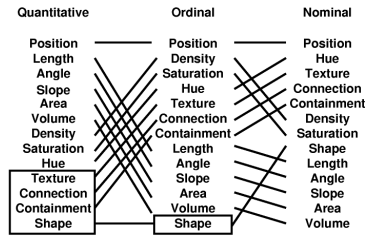
Dimensional ranking varies by data type

spatial position best for all types



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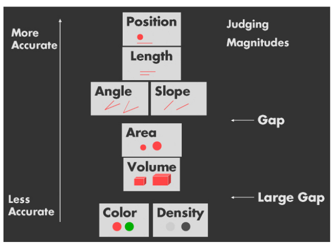
[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]

Dimensional ranking



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

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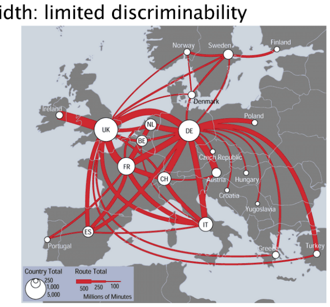
Dimensional dynamic range

linewidth: limited discriminability



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

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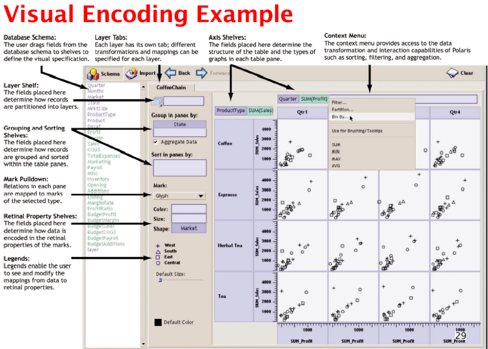
Visual Encoding Example



[Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan,

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Ears

perceived as temporal stream
- but also samples over time
- hard to filter out when not important
  - visual vs auditory attention

implications
- harder to create overview?
- hard to use as separable dimension?

'sonification' still very niche area
- alternative: supporting sound enhances immersion

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Color rules of thumb

nominal
- bad: > 12 hues
- good: use <= ~12 hues

ordinal
- bad: using hue
- good: saturation/brightness

quantitative
- bad: rainbow colormaps
- good: interpolate between two hues

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

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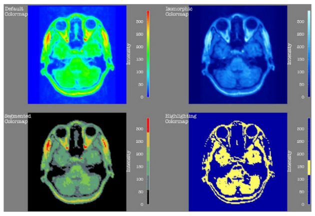
Colormaps

rainbow colormaps usually bad idea
- hue is mediocre for showing order
- not perceptually linear!



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

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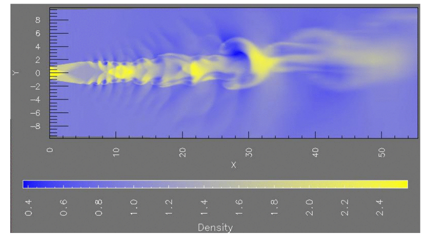
Colormaps

interpolating between two hues usually safe



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

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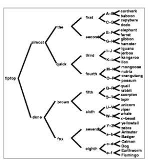
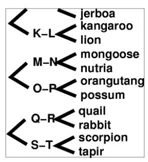
Overview+detail

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

bad: one window, must remember position



global overview



local detail

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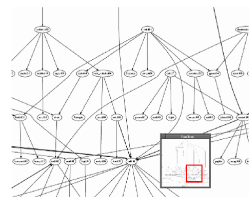
Overview and detail

better: add linked overview window(s)



how to create overview?

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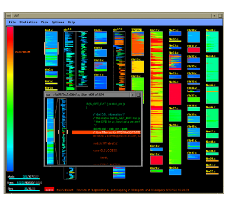
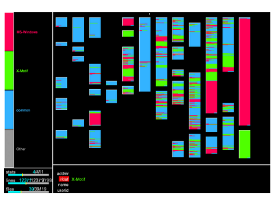
Overview and detail

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]

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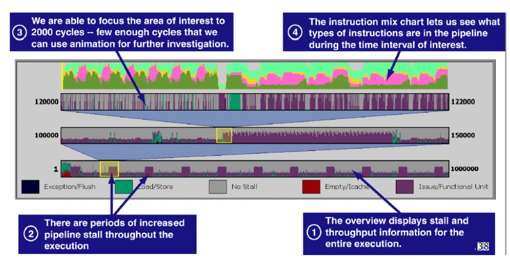
Overview+detail

Rivet: performance tuning
- level of detail



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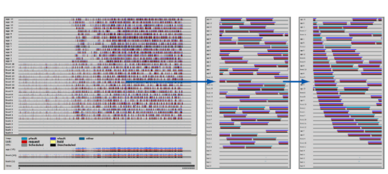
Overview to detail to sorting



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

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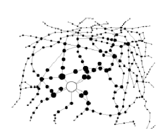
Focus+context

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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Focus+context

linked windows
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good solution:
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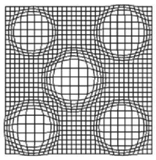
fisheye views [Furnas 86], [Sarkar et al 94]
nonlinear magnification [Keahey 96]



TableLens

focus+context
power of sorting

www.tablelens.com

Focus+context

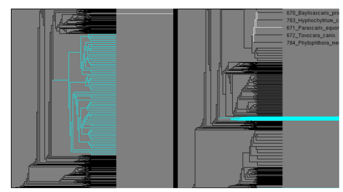
H3 [Munzner 97]
- task: browsing large quasi-hierarchical graphs
- [demo]

[Munzner 1997, 1998a, 1998b]

Global focus+context

TreeJuxtaposer: comparing trees

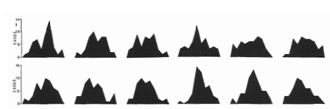
- linked highlighting
- [demo]



Comparison

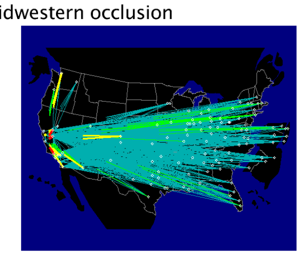
bad: temporal, if many items
- intermediate ones "overload mental buffer"
- good: temporal blinking if two items

good: side by side
- array of small multiples
- creates overview



Minimizing occlusion

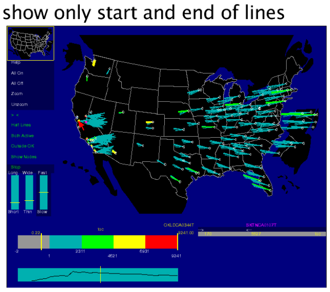
bad: Midwestern occlusion



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

Minimizing occlusion

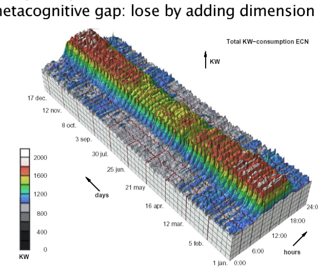
good: show only start and end of lines



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

Minimizing occlusion: 3D vs. 2D

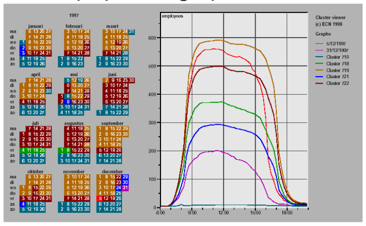
bad: 3D pretty but not useful
- metacognitive gap: lose by adding dimension



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

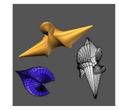
Minimizing occlusion: 3D vs. 2D

good: 2D display of category clusters

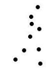


[van Wijk and van Selow, Cluster and Calender based Visualization of Time Series Data, InfoVis99, citeseer.nj.nec.com/vanwijk99cluster.html]

Motion: clarify structure



navigation
- rotate/translate/zoom
- [demo: Geomview]



[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

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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: 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

More Information

UBC Term 2 course: 533C Visualization
- undergrads by consent of instructor

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