Lecture 5: Perception

Information Visualization
CPSC 533C, Fall 2006

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Readings Covered

Ware, Chapter 5: Visual Attention and Information That Pops Out

Ware, Chapter 6: Static and Moving Patterns

Ware, Chapter 11: Thinking With Visualizations

Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

Human Perception

- sensors/transducers
  - psychophysics: determine characteristics
- relative judgements: strong
- absolute judgements: weak
  - continuing theme
- different optimizations than most machines
  - eyes are not cameras
  - perceptual dimensions not nD array
  - (brains are not hard disks)

Foveal Vision

- thumbnail at arm's length

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.htm]

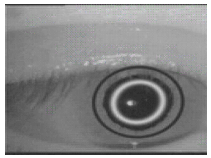
Equal Legibility

- if fixated on center point

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

Eyes

- saccades [video]
  - 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/

Ears

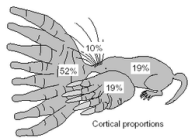
- perceived as temporal stream
  - but also samples over time
  - hard to filter out when not important
    - visual vs auditory attention
- implications
  - harder to create overview?
  - hard to use as separable dimension?
- 'sonification' still very niche area
  - alternative: supporting sound enhances immersion

Other Modalities

- barrier: lack of record/display technology
- haptics maturing
  - "haptic visualization" very new
- smell, taste
  - out-there SIGGRAPH ETech demos
  - characterization possible after technology barriers fall

Foveal Touch

- star-nosed mole



[www.nature.com/nsu/010329/010329-6.html]
[brain.nips.ac.jp/event/work131030/Catania_and_Kaas_.1997.pdf]

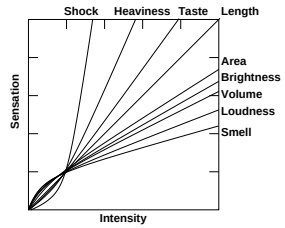
Psychophysical Measurement

- JND: just noticeable difference
- increment where human detects change
- average to create "subjective" scale
- low-level perception more uniform than high-level cognition across subjects

Nonlinear Perception of Magnitudes

sensory modalities not equally discriminable

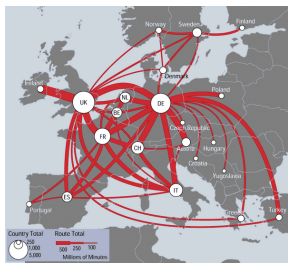
Stevens' Power Law: $I = S^P$



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

Dimensional Dynamic Range

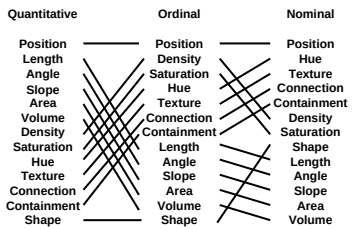
- linewidth: limited discriminability



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

Dimensional Ranking: Accuracy

- spatial position best for all types



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

Cleveland vs. Mackinlay: Quantitative

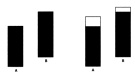
Mackinlay	Cleveland
position	position along common scale position along nonaligned scales
length angle slope	length, direction, angle
area volume density saturation hue texture connection containment shape	area volume, curvature shading, color saturation

Weber's Law

- ratio of increment threshold to background intensity is constant
  - relative judgements within modality

$$\frac{\Delta I}{I} = K$$

- Cleveland example: frame increases accuracy



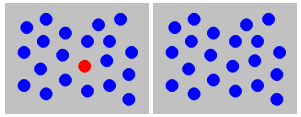
Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models. William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

Cleveland Suggestions

- dot chart over pie or bars
- direct differences over superimposed curves
- framed rectangles over shading on maps

Preattentive Visual Dimensions

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

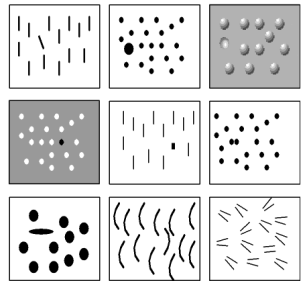


- demo

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

Many Preattentive Visual Dimensions

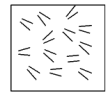
hue
shape
texture
length
width
size
orientation
curvature
intersection
intensity
flicker
direction of motion
stereoscopic depth
light direction, . . .



[www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Not All Dimensions Preattentive

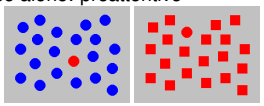
parallelism



[www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive Visual Dimensions

- color alone: preattentive
- shape alone: preattentive

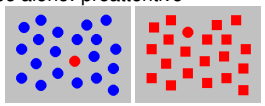


- combined hue and shape (demo)

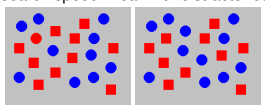
[www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive Visual Dimensions

- color alone: preattentive
- shape alone: preattentive



- combined hue and shape (demo)
  - requires attention
  - search speed linear with distractor count



[www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Separable vs. Integral Dimensions

- not all dimensions separable

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

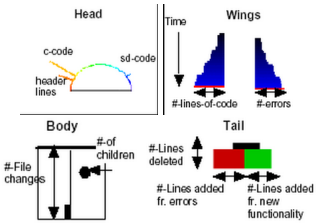
[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

Glyphs

- composite graphical mark
- encoding using multiple dimensions
- large-scale individual glyphs vs. small-scale texture fields
  - grouping into large-scale patterns
- integral vs. separable analysis
  - when do they help?

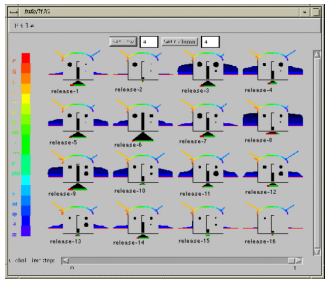
Glyphs: InfoBug

- software management



[Information Rich Glyphs for Software Management, IEEE CG&A 18:4 1998, www.cs.cmu.edu/~sage/Papers/CGAglyph/CGAglyph.pdf]

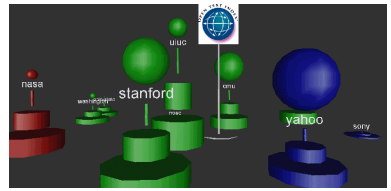
Glyphs: InfoBug Small Multiples Array



[Information Rich Glyphs for Software Management, IEEE CG&A 18:4 1998, www.cs.cmu.edu/~sage/Papers/CGAglyph/CGAglyph.pdf]

Glyphs: Bray

- Web sites circa 1996
  - # pages: base diameter
  - # outlinks: globe diameter
  - # inlinks: height
  - domain: hue



Bray, Measuring the Web, WWW5, 1996. www5conf.inria.fr/fich_html/papers/P9/Overview.html

Gestalt Laws

- principles of pattern perception
  - "gestalt": German for "pattern"
  - original proposed mechanisms wrong
  - rules themselves still useful
- Pragnatz
  - simplest possibility wins

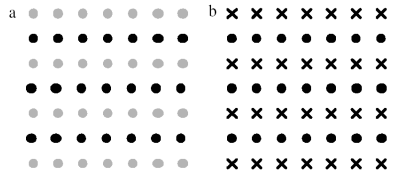
Gestalt Principles

- proximity, similarity, continuity/connectedness/good continuation
- closure, symmetry
- common fate (things moving together)
- figure/ground, relative sizes

Proximity

[Information Visualization: Perception for Design. Ware, Morgan Kaufmann, 2000]

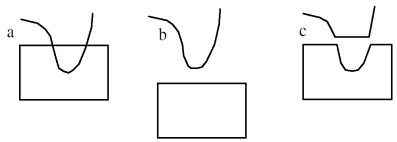
Similarity



[Information Visualization: Perception for Design. Ware, Morgan Kaufmann, 2000]

Continuity

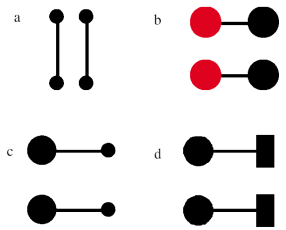
- smooth not abrupt change
- overrules proximity



[Information Visualization: Perception for Design. Ware, Morgan Kaufmann, 2000]

Connectedness

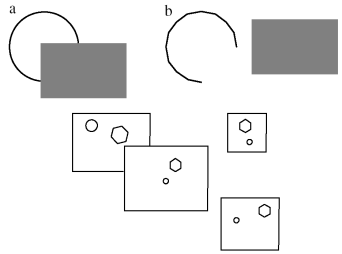
- can overrule size, shape



[Information Visualization: Perception for Design. Ware, Morgan Kaufmann, 2000]

Closure

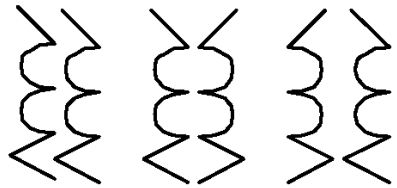
- overrules proximity



[Information Visualization: Perception for Design. Ware, Morgan Kaufmann, 2000]

Symmetry

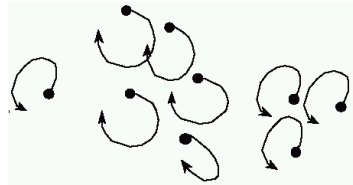
- emphasizes relationships



[Information Visualization: Perception for Design. Ware, Morgan Kaufmann, 2000]

Common Fate

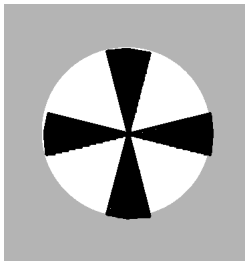
- demo
- tepserver.ucsd.edu/~jlevin/gp/time-example-common-fate



[Information Visualization: Perception for Design. Ware, Morgan Kaufmann, 2000]

Relative Size

- smaller components perceived as objects



[Information Visualization: Perception for Design. Ware, Morgan Kaufmann, 2000]

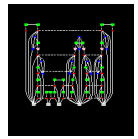
Figure/Ground

- determined by combination of previous laws

[Information Visualization: Perception for Design. Ware, Morgan Kaufmann, 2000]

Graph Drawing Tension

- node placement
- close
  - proximity
- far
  - visual popout of long edge
- either
  - connectedness
- tradeoffs abound in infovis!
- grammars
  - node-link graphs
  - maps



[www.research.att.com/sw/tools/graphv

Motion

- works for preattentive/grouping
- less studied than static dimensions
  - Michotte on causality
  - newer infovis/motion work by Lyn Bartram
- biological motion
  - demo

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

Thinking With Viz

- problem solving loops
  - external representations
  - cognitive cyborgs
- cost of knowledge
  - Pirolli/Rao: information foraging/scent theory
  - attention as most limited resource

Visual Working Memory

- characteristics
  - different from verbal working memory
  - low capacity (3-5?)
  - locations egocentric
  - controlled by attention
  - time to change attention: 100 ms
  - time to get gist: 100 ms
  - not fed automatically to long term memory

Visual Working Memory

- multiple attributes per object stored
  - position (egocentric), shape, color, texture
    - integration into glyphs allows more info
- change blindness (Rensink)
  - world is its own memory
- inattentional blindness
- attracting attention
  - motion (or appear/disappear?)

Memory and Loops

- long term memory
  - chunking
  - memory palaces (method of loci)
- nested loops
  - problem-solving strategy
  - visual query construction
  - pattern-finding loop
  - eye movement control loop
  - intrasaccadic image-scanning loop

InfoVis Implications

- visual query patterns
- navigation/interaction cost
- multiple window vs. zoom

More Perception

- Rensink grad course taught every few years
  - Perceptual Issues in Visual Interface Design, CPSC 532E Jan 2003 http://www.cs.ubc.ca/~rensink/courses/cpsc532E/
  - Special Topics in Perception: Visual Display Design, PSYCH 579 Jan 2006 http://www.psych.ubc.ca/~rensink/courses/psyc579/