

Lecture 5: Perception

Information Visualization
CPSG 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



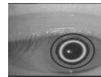
Equal Legibility

- if fixated on center point



Eyes

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



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

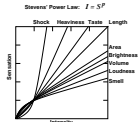


Psychophysical Measurement

- 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, On the Theory of Scale of Measurement, Science 50:218, 1948]

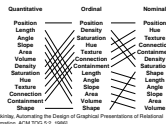
Dimensional Dynamic Range

- linewidth: limited discriminability



Dimensional Ranking: Accuracy

- spatial position best for all types



Cleveland vs. Mackinlay: Quantitative

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

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



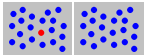
Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models, William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

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

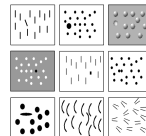


- demo

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

Many Invariant 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

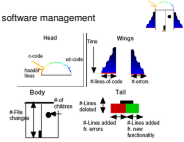
[Colin Ware, Information Visualization: Perception for Design, Morgan Kaufmann 1999.]

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?

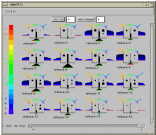
Glyphs: InfoBug

- software management



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

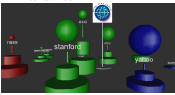
Glyphs: InfoBug Small Multiples Array



[Information Rich Glyphs for Software Management, IEEE CGAA 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, WWW9, 1996, www.conf.inria.fr/ich_wm/papers/P96overview.html


Gestalt Laws

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

Gestalt Principles

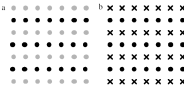
- proximity, similarity, continuity/connectedness/good continuation
- closure, symmetry
- common fate (things moving together)
- figure/ground, relative sizes

Proximity



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

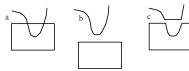
Similarity



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

Continuity

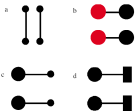
- smooth not abrupt change
- overrides proximity



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

Connectedness

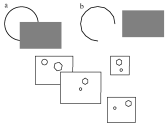
- can overrule size, shape



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

Closure

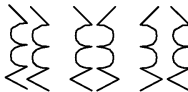
- overrides proximity



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

Symmetry

- emphasizes relationships



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

Common Fate

- demo
- lepever.ucsd.edu/~levin/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/lex/lec4/graphs]

[www.research.att.com/lex/lec4/graphs]

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/bipwajser.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

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

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

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

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
- inattention blindness
- attracting attention
 - motion (or appear/disappear?)

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

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

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

InfoVis Implications

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

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

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/>

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