Lecture 5: Perception

Information Visualization
CPSC 533C, Fall 2006

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25 September 2006

Readings Covered

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

Ware, Chapter 6: Static and Moving Patterns

The Psychophysics of Sensory Function, S. S. Stevens, Sensory Communication, MIT Press, 1961, pp 1-33.

Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models William S. Cleveland, Robert McGill, J. Amer. 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/fovea/tion.html]

MPEG WORLD

MPEG WORLD

[sci.cas.utexas.edu/examples_foveated.jpeg]

Equal Legibility

- if fixated on center point

[psy.ucsd.edu/~sanella/SAIBlur.html]

Foveal Touch

- star-nosed mole

[www.nature.com/nsu/010229/010229-6.html]
[brain.nips.ac.jp/event/work/131/030/Catania_and_Kaas_1997.pdf]

Eyes

- saccades [video]
  - fovea: high-resolution samples
  - brain makes collage
  - vision perceived as entire simultaneous field
  - fixation points: dwell 200-600ms
  - moving: 20-100ms
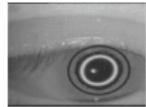
[vision.arc.nasa.gov/personnel/jbm/home/projects/oat/oat08.html]

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

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

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Nonlinear Perception of Magnitudes

sensory modalities **not** equally discriminable

Stevens' Power Law: $I = S^P$
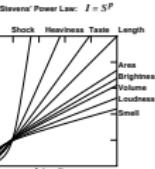
[Stevens, On the Theory of Scales of Measurement, Science 103:2684, 1946]

Dimensional Dynamic Range

- linewidth: limited discriminability

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

Dimensional Ranking: Accuracy

- spatial position best for all types

Quantitative	Ordinal	Nominal
Position	Position	Position
Length	Density	Hue
Angle	Saturation	Texture
Slope	Hue	Connection
Area	Texture	Containment
Volume	Connection	Density
Density	Containment	Saturation
Saturation	Length	Shape
Hue	Angle	Length
Texture	Slope	Angle
Connection	Area	Slope
Containment	Volume	Area
Shape	Shape	Volume
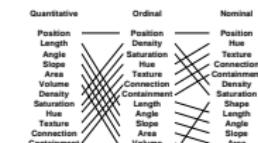
[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]

Cleveland vs. Mackinlay: Quantitative

Mackinlay	Cleveland
position	position along common scale
	position along nonaligned scales
length	length, direction, angle
angle	
slope	
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
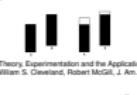
Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models. William S. Cleveland, Robert McGill, J. Amer. Stat. Assoc. 79:387, pp. 531-554, 1984.

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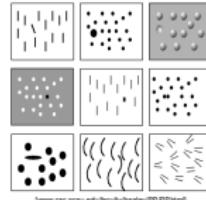
[www.csc.ncsu.edu/faculty/healey/PP/PP.html]

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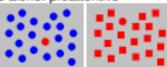
[www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive Visual Dimensions

- color alone: preattentive
- shape alone: preattentive

- combined hue and shape (demo)
  - requires attention
  - search speed linear with distractor count
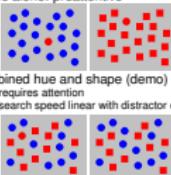
[www.csc.ncsu.edu/faculty/healey/PP/PP.html]

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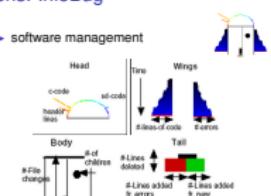
[Information Rich Glyphs for Software Management, IEEE CG&A 18:4 1998, www.cs.cmu.edu/~ssage/Papers/CGAglyph/CGAglyph.pdf]


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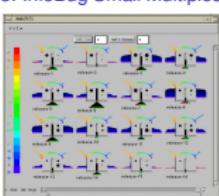
[Information Rich Glyphs for Software Management, IEEE CG&A 18:4 1998, www.cs.cmu.edu/~ssage/Papers/CGAglyph/CGAglyph.pdf]

Glyphs: Bray

- Web sites circa 1996
  - # pages: base diameter
  - # outlinks: globe diameter
  - # inlinks: height
  - domain: hue
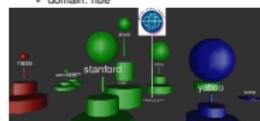
[Bray, Measuring the Web, WWW5, 1996, www5conf.inria.fr/fich_html/papers/P9/Overview.html]

Gestalt Laws

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


Gestalt Principles

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

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

Proximity

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

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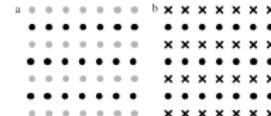
[Information Visualization: Perception for Design, Ware, Morgan Kaulmann, 2000]


Continuity

- smooth not abrupt change
- overrules proximity

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

Connectedness

- can overrule size, shape
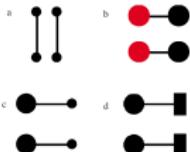
Closure

- overrules proximity
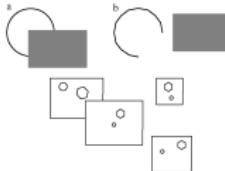
Symmetry

- emphasizes relationships
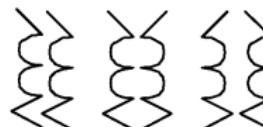
Common Fate

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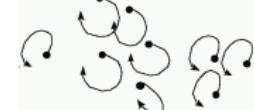
Relative Size

- smaller components perceived as objects
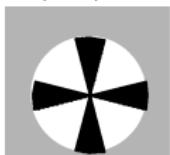
Figure/Ground

- determined by combination of previous laws

Graph Drawing Tension

- node placement
- close
  - proximity
- far
  - visual popout of long edge
- either
  - connectedness

- tradeoffs abound in infovis! [www.research.att.com/sw/tools/graphv...]
- grammars
  - node-link graphs
  - maps

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/bigwalker.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/

Presentation Topic Choices