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
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/](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]
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: \( I = S^p \)

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

<table>
<thead>
<tr>
<th>Mackinlay</th>
<th>Cleveland</th>
</tr>
</thead>
<tbody>
<tr>
<td>position</td>
<td>position along common scale</td>
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<tr>
<td></td>
<td>position along nonaligned scales</td>
</tr>
<tr>
<td>length</td>
<td>length, direction, angle</td>
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<tr>
<td>angle</td>
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<tr>
<td>slope</td>
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<td>area</td>
<td>area</td>
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<td>volume</td>
<td>volume, curvature</td>
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<tr>
<td>density</td>
<td>shading, color saturation</td>
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<tr>
<td>saturation</td>
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<tr>
<td>hue</td>
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<tr>
<td>texture</td>
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<tr>
<td>connection</td>
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<tr>
<td>containment</td>
<td></td>
</tr>
<tr>
<td>shape</td>
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</tbody>
</table>
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

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

[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, ...
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

[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

Glyphs: InfoBug Small Multiples Array

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
    http://www.cs.ubc.ca/~rensink/courses/cpsc532E/
    http://www.psych.ubc.ca/~rensink/courses/psyc579/