Lecture 5: Visual Encoding Principles

Information Visualization
CPSC 533C, Fall 2011

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UBC Computer Science

Wed, 21 September 2011

Required Readings

Chapter 3: Visual Encoding Principles
(this time: first 25 pages, Sec 3.1-3.4)
(next time: last 11 pages, Sec 3.5)

Representing Colors as Three Numbers, Maureen Stone, IEEE CG&A 25(4):78-85, Jul 2005.

Further Reading

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. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

Automating the Design of Graphical Presentations of Relational Information. Jock Mackinlay, ACM Transaction on Graphics, vol. 5, no. 2, April 1986, pp. 110-141.

Semiology of Graphics. Jacques Bertin, Gauthier-Villars 1967, EHESS 1998

The Grammar of Graphics. Leland Wilkinson, Springer-Verlag 1999

Further Reading

Stone. Color In Information Display. IEEE Visualization 2006 Course Notes. http://www.stonesc.com/Vis06

A Field Guide To Digital Color, Maureen Stone, AK Peters 2003.

Tufte, Envisioning Information. Chapter 5: Color and Information

Ware, Information Visualization: Perception for Design:

Ch 3: Lightness, Brightness, Contrast, and Constancy

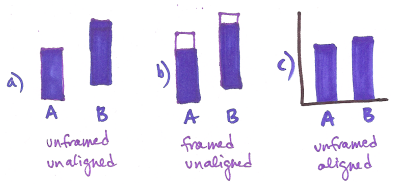
Ch 4: Color

Ch 5: Visual Attention and Information That Pops Out

Ch 6: Static and Moving Patterns

Ch 8: Space Perception and the Display of Data in Space

Relative vs Absolute Perception: Length

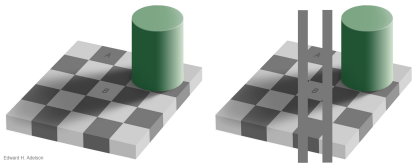


- Weber's Law: relative judgements
  - ratio of increment threshold to background intensity is constant

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

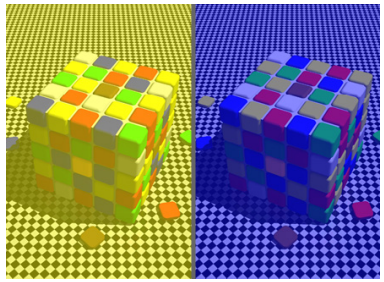
  - filled rectangles vs white rectangles

Relative vs Absolute Perception: Lightness



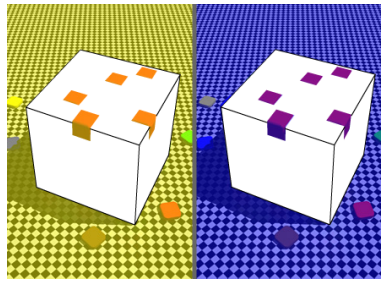
[Edward H. Adelson, http://persci.mit.edu/_media/gallery/checkershadow_double_full.jpg]

Relative vs Absolute Perception: Color



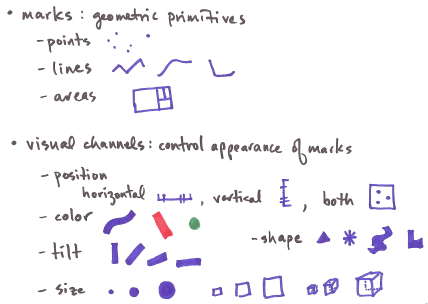
[Purves. http://www.purveslab.net/seeforyourself/]

Relative vs Absolute Perception: Color

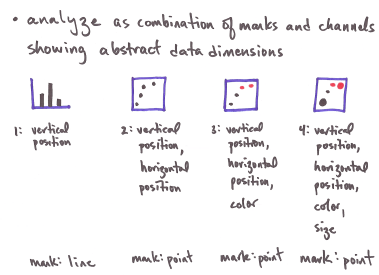


[Purves. http://www.purveslab.net/seeforyourself/]

Image Theory

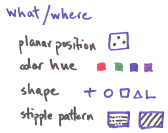


Visual Encoding



Visual Channel Types and Rankings

Visual Channel Types and Rankings



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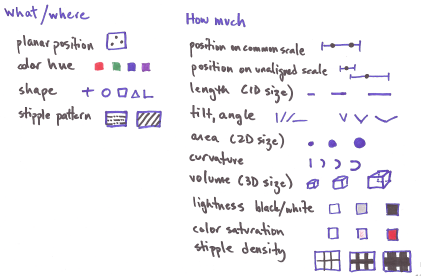

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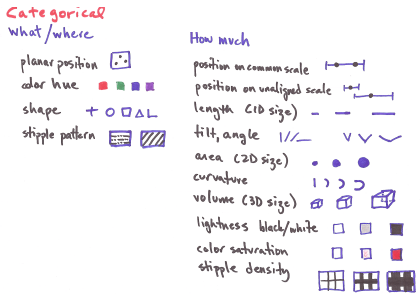

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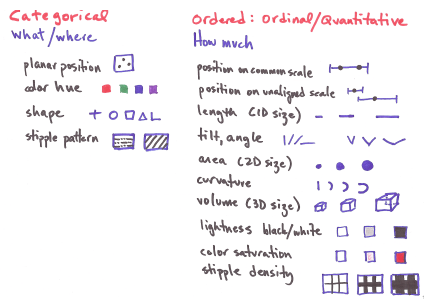

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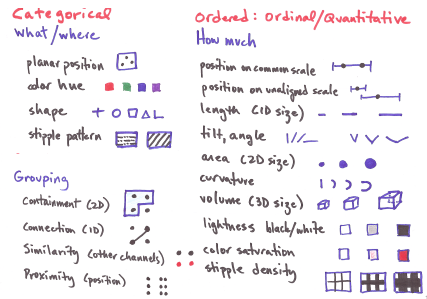
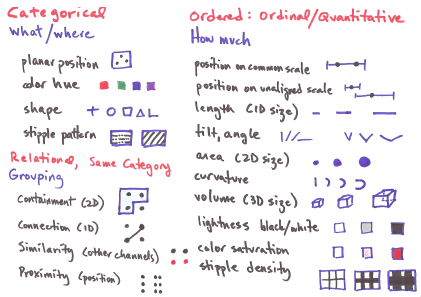
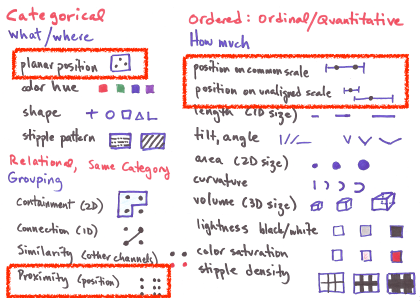


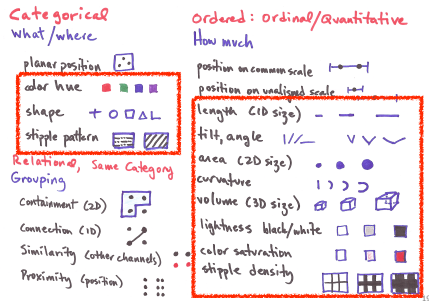
Visual Channel Types and Rankings



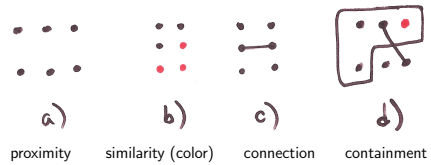
Only Planar Position Works For All!



Ranking Differs For All Other Channels



Grouping Channels

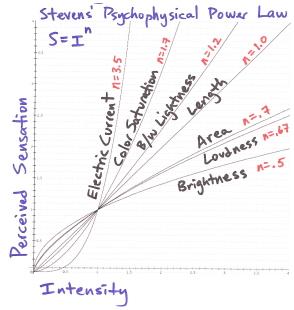


proximity similarity (color) connection containment

Expressiveness and Effectiveness

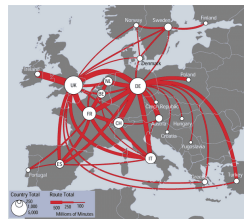
- expressiveness principle
  - pick visual channel to express all of and only information in dataset
- effectiveness principle
  - ranking of channel should match importance of attribute
- what criteria determine channel ranks?
  - accuracy, discriminability, separability, popout
  - grouping precedence

Accuracy



Discriminability

- limits on available dynamic range



Separability vs. Integrality

Separability vs. Integrality

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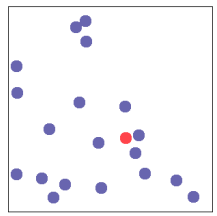
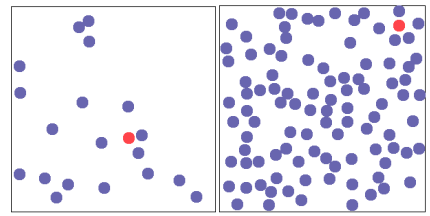
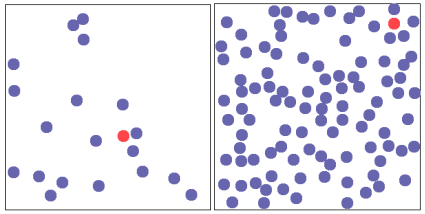
Visual Popout



Visual Popout

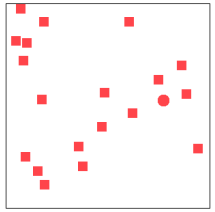


Visual Popout

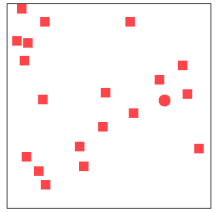


- parallelism: independent of distractor count

Visual Popout

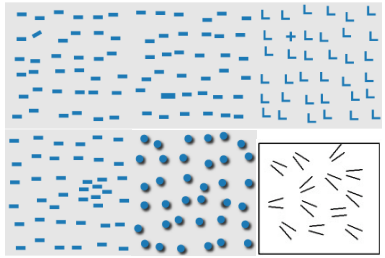


Visual Popout

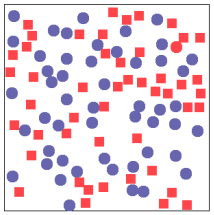


- speed depends on: which channel, difference from surroundings
  - 'sufficiently different' is context dependent

Popout Channels: Many But Not All

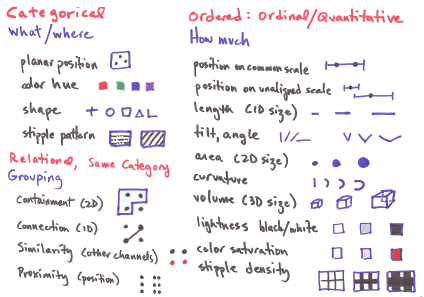


Popout Limits



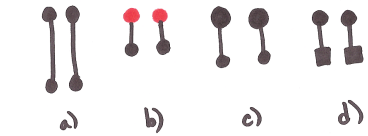
- combination searches are serial
  - exception: a few pairs

Visual Channel Types and Rankings



Grouping: Precedence Not Effectiveness

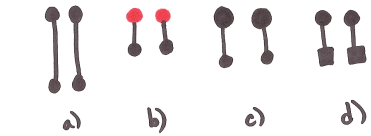
- all channels effective; rank is order of precedence



proximity similarity (color) sim (size) sim (shape)

Grouping: Precedence Not Effectiveness

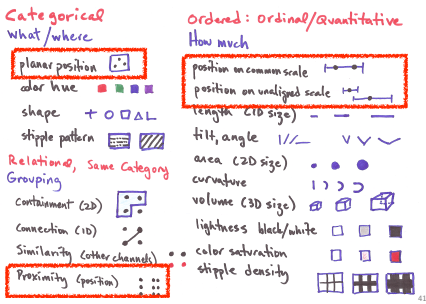
- all channels effective; rank is order of precedence



proximity similarity (color) sim (size) sim (shape)

containment overrides connection

Power of Planar Position

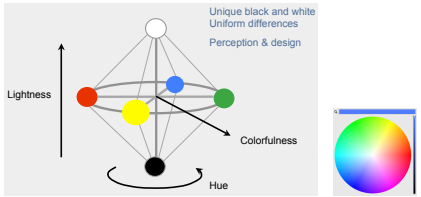


Color Vision Process

- rods
  - B/W info in low-light conditions
  - not discussed further
- 3 cone types
  - sensors: RGB
- 3 opponent color channels
  - one luminance: black/white
  - two "color": red/green, blue/yellow
  - color deficiency
    - one hue channel collapsed
    - sex-linked mutation: 8% of men, .5% of women

Luminance, Saturation, Hue

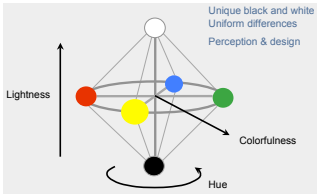
- luminance: how much
- saturation: how much
- hue: what



[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85]

Ordered: Lum/Sat, Unordered: Hue

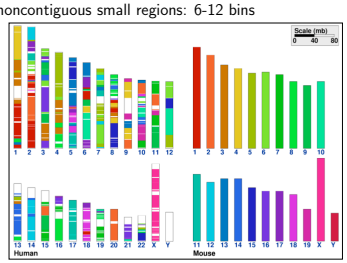
- luminance: how much
- saturation: how much
- hue: what



[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85]

Discriminablity: Categorical Color

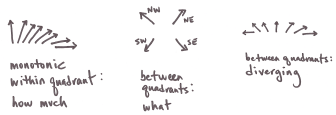
- noncontiguous small regions: 6-12 bins



[Sinha and Meller. Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Bioinformatics 2007]

Other Channels

- size: how much
  - small sizes interfere with many other channels
- tilt/angle: both



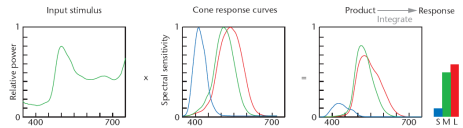
- shape: what
- stipple: how much
  - interferes with luminance
- motion: how much
  - grabs attention, difficult to attend to other channels

Color As Three Numbers

Stone
Representing Color As Three Numbers, CG&A 25(4):78-85

Trichromacy

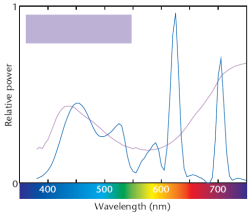
- different cone responses area function of wavelength
- for a given spectrum
  - multiply by response curve
  - integrate to get response



[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

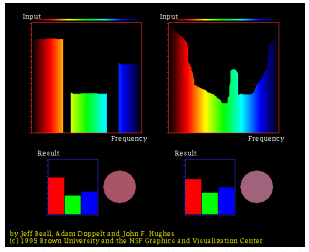
Metamerism

- brain sees only cone response
- different spectra appear the same



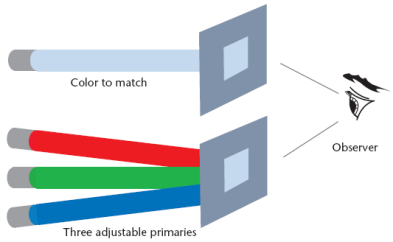
[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

Metamerism Demo



[www.cs.brown.edu/exploratories/freeSoftware/repository/edu/brown/cs/exploratories/applets/spectrum/metamers_java_browser.html]

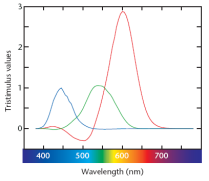
Color Matching Experiments



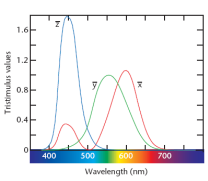
[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

Color Matching Functions

Stiles-Burch, negative lobe



CIE standard, all positive

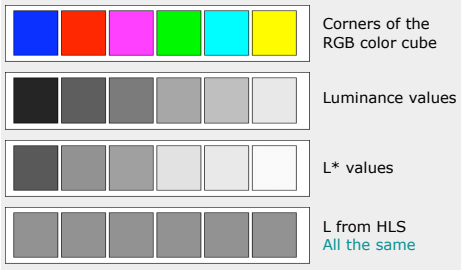


[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

Color Spaces

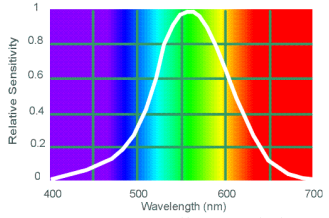
- RGB: convenient for machines
  - these three channels **not** separable
- CIE XYZ: from color matching functions
  - perceptually based
- L*a*b*: from XYZ + reference whitepoint
  - perceptually linear, safe to interpolate
- HLS: simple transformation of RGB
  - good: separates out lightness, hue, saturation channels
  - bad: lightness **not** true luminance
  - careful: only **pseudo**-perceptual!

Lightness vs Luminance



[Stone. Color In Information Display. IEEE Visualization 2006 Course Notes. http://www.stonesc.com/Vis06]

Spectral Sensitivity



[Joy of Visual Perception, Peter Kaiser. http://www.yorku.ca/eye/photopik.htm]