

## Lecture 5: Visual Encoding Principles

Information Visualization  
CPSG 533C, Fall 2011

Tamara Munzner  
UBC Computer Science  
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### 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.

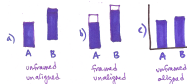
### Further Reading

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. Jack 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

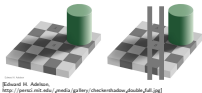
Stone. Color In Information Display. IEEE Visualization 2005  
Course Notes. <http://www.stonevc.com/Vi05>  
A Field Guide To Digital Color, Maureen Stone, AK Peters 2003  
Tuft, Envisaging Information. Chapter 5: Color and Information  
Ware, Information Visualization: Perception for Design:  
Ch 3: 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



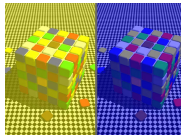
- Weber's Law: relative judgements
    - ratio of increment threshold to background intensity is constant
- $$\frac{\Delta I}{I} = K$$
- filled rectangles vs white rectangles

### Relative vs Absolute Perception: Lightness



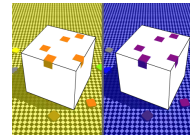
Revised 10. Addition.  
[http://percc.net/edu/graphics/checkerboard.html#lightness\[26\]](http://percc.net/edu/graphics/checkerboard.html#lightness[26])

### Relative vs Absolute Perception: Color



[Picture: <http://www.percc.net/edu/graphics/>]

### Relative vs Absolute Perception: Color



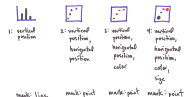
[Picture: <http://www.percc.net/edu/graphics/>]

### Image Theory

- marks: geometric primitives
  - points
  - lines
  - areas
- visual channels: control appearance of marks
  - position: horizontal  $\leftarrow$ , vertical  $\uparrow$ , both  $\leftarrow \uparrow$
  - color:  $\leftarrow$   $\uparrow$   $\leftarrow \uparrow$
  - tilt:  $\leftarrow$   $\uparrow$   $\leftarrow \uparrow$
  - size:  $\leftarrow$   $\uparrow$   $\leftarrow \uparrow$

### Visual Encoding

- analyze as combination of marks and channels showing abstract data dimensions



mark: line mark: point mark: point mark: point

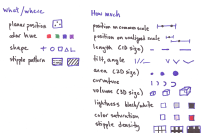
### Visual Channel Types and Rankings

What/where

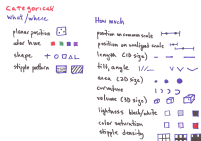
How much



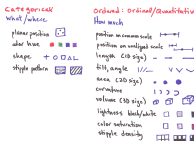
### Visual Channel Types and Rankings



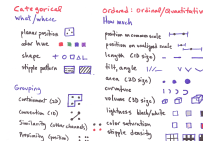
### Visual Channel Types and Rankings



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### Visual Channel Types and Rankings



### Visual Channel Types and Rankings

**Categorical**  
What/where

**Ordinal: Ordinal/Quantitative**  
How much

plane position  
color hue  
shape  
style pattern  
Relation: Size Coding  
Grouping  
Contrast (C0)  
Concavity (C1)  
Similarity (Other channel)  
Proximity (Spatial)

position on common scale  
position on unaligned scale  
length (C0 sig)  
fill, angle  
area (C0 sig)  
volume (C0 sig)  
curvature  
lightness/black/white  
color saturation  
stroke density

### Only Planar Position Works For All

**Categorical**  
What/where

**Ordinal: Ordinal/Quantitative**  
How much

plane position  
color hue  
shape  
style pattern  
Relation: Size Coding  
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stroke density

### Ranking Differs For All Other Channels

**Categorical**  
What/where

**Ordinal: Ordinal/Quantitative**  
How much

plane position  
color hue  
shape  
style pattern  
Relation: Size Coding  
Grouping  
Contrast (C0)  
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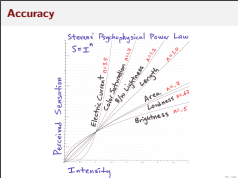
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stroke density

### Grouping Channels

a) proximity  
b) similarity (color)  
c) connection  
d) 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



### Discriminability

- limits on available dynamic range

### Separability vs. Integrality

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position hue (color)  
size hue (color)  
size:width size:height  
red green

fully separable

2 groups each

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fully separable

some interference

2 groups each {2 groups each}

### Separability vs. Integrality

position hue (color)  
size hue (color)  
size:width size:height  
red green

fully separable

some interference

some significant interference

difficult to discriminate small items (plane sig)

2 groups each {2 groups each} 3 groups

### Separability vs. Integrality

position hue (color)  
size hue (color)  
size:width size:height  
red green

fully separable

some interference

some significant interference

difficult to discriminate small items (plane sig)

major interference

integrated percept: area (plane sig)

integrated percept: color/hue

2 groups each {2 groups each} 3 groups 4 groups

### Separability vs. Integrality

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### Visual Popout

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- parallelism: independent of distractor count

### Visual Popout

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- 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

**Categorical**  
What/where

- plane position
- color hue
- shape
- style/pattern

**Ordinal: Orient/quantitative**  
How much

- position on common scale
- position on ordinal scale
- length (EB sig)
- fit, angle
- area (2D sig)
- curvature
- volume (3D sig)
- lightness black/white
- color saturation
- stipple density

**Relative, Size Coding**

- contourness (2D)
- convexity (2D)
- Similarity (color channel)
- Proximity (spatial)

### Grouping: Precedence Not Effectiveness

- all channels effective; rank is order of precedence

a) proximity    b) similarity (color)    c) sim (size)    d) sim (shape)

### Grouping: Precedence Not Effectiveness

- all channels effective; rank is order of precedence

a) proximity    b) similarity (color)    c) sim (size)    d) sim (shape)

containment overrides connection

### Power of Planar Position

**Categorical**  
What/where

- plane position
- color hue
- shape
- style/pattern

**Ordinal: Orient/quantitative**  
How much

- position on common scale
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**Relative, Size Coding**

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### Color Vision Process

- rods
- 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, CGEA 25(4):78-85]

### Ordered: Lum/Sat, Unordered: Hue

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

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

### Discriminability: Categorical Color

- noncontiguous small regions: 6-12 bins

[Stevens and Miller, Categorical: Flexible analysis and visualization of systems and process arrangements in multiple systems, 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, CGEA 25(4):78-85

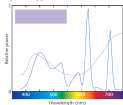
### Trichromacy

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

[Stone, Representing Color As Three Numbers, CGEA 25(4):78-85, www.stonem.com/pubs/Stone%20CGA%2025(4):78-85.pdf]

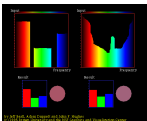
## Metamerism

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



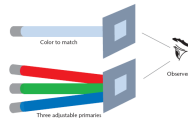
[Stone, Representing Color As Three Numbers, CGFA 25(4) 79-85, [www.stonec.com/pubs/Stone%20CGFA%2025%2004.pdf](http://www.stonec.com/pubs/Stone%20CGFA%2025%2004.pdf)]

## Metamerism Demo



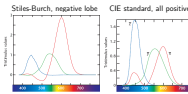
[[www.cs.brown.edu/~explorations/teach/Software/repository/edu/sereno/cs/explorations/applepie/1spec.html](http://www.cs.brown.edu/~explorations/teach/Software/repository/edu/sereno/cs/explorations/applepie/1spec.html); [metamerism.giv-a-better.com](http://metamerism.giv-a-better.com/)]

## Color Matching Experiments



[Stone, Representing Color As Three Numbers, CGFA 25(4) 79-85, [www.stonec.com/pubs/Stone%20CGFA%2025%2004.pdf](http://www.stonec.com/pubs/Stone%20CGFA%2025%2004.pdf)]

## Color Matching Functions

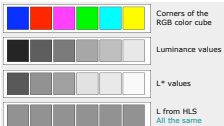


[Stone, Representing Color As Three Numbers, CGFA 25(4) 79-85, [www.stonec.com/pubs/Stone%20CGFA%2025%2004.pdf](http://www.stonec.com/pubs/Stone%20CGFA%2025%2004.pdf)]

## Color Spaces

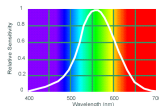
- RGB: convenient for machines
  - these three channels **not** separable
- CIE XYZ: from color matching functions
  - perceptually based
- L\*a\*b\*: from XYZ → reference whitepoint
  - perceptually linear; safe to interpolate
- HLS: simple transformation of RGB
  - good: separates out lightness, hue, 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.stonec.com/Vid06/>]

## Spectral Sensitivity



[Joy of Visual Perception, Peter Kaiser, <http://www.park.ca/eye/photopak.html>]