IAT 814
Visual Encoding 2

Colour in Information Display

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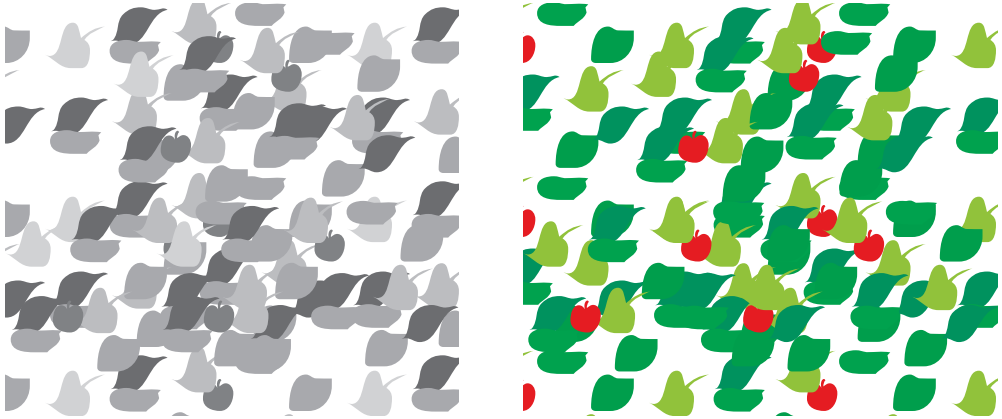
SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Colour is Irrelevant…

- To perceiving object shapes
- To perceiving layout of objects in space
- To perceiving how objects are moving
- Therefore, to much of modern life
  - Laboratory assistant went 21 years without realizing he was colour-blind

Colour is Critical…

- To help us break camouflage
- To judge the condition of objects (food) > surfaces
- To determine material types
- Extremely useful for coding information

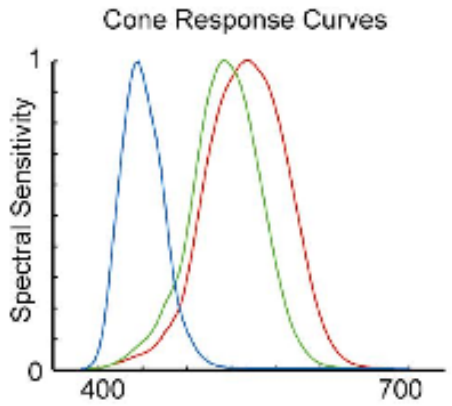


What about colour?

- Colour perception is *relative*
- We are sensitive to small differences
  - hence need sixteen million colours
- Not sensitive to absolute values
  - hence we can only use < 10 colours for coding

Cone Response (photopic)

- Cone response sensitivity for colours occurs at different wavelengths in the spectrum
  - Cone response curve
  - Long, medium and short (LMS)

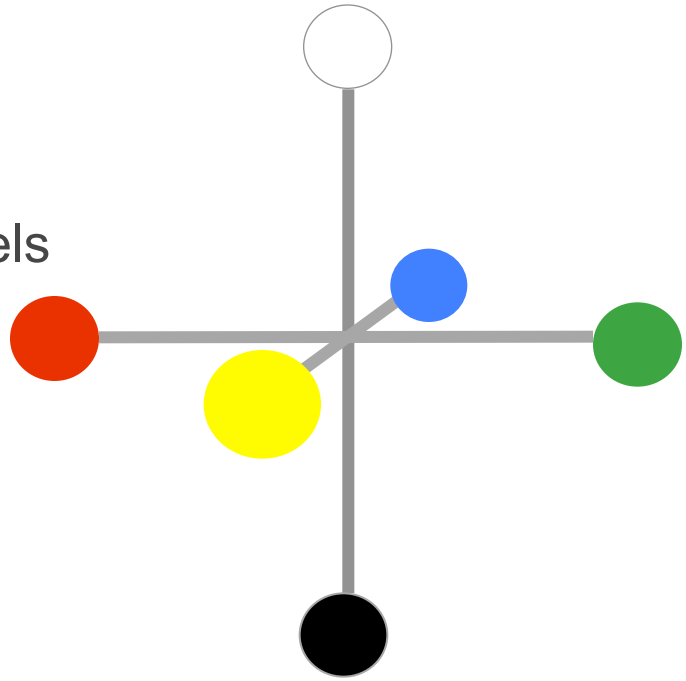


- Sort of like a digital camera*
  - BUT light sensors in a camera are equally distributed
- Uneven cone distribution
  - saccades for continuous image

From *A Field Guide to Digital Color*, © A.K. Peters, 2003

Opponent Color

- Definition
  - Achromatic axis
  - R-G and Y-B axis
  - Separate lightness from chroma channels
- First level encoding
  - Linear combination of LMS
  - Before optic nerve
  - Basis for perception
  - Defines “color blindness”



Comparing the Channels

- Spatial Sensitivity
  - Red/Green and Yellow/Blue about 1/3 detail of Black/White
- Stereoscopic Depth
  - Pretty much can't do it with hue alone
- Luminance contrast is critical
  - Especially with small patterns
- Form
  - Shape-from shading works well
  - Shape-from-hue doesn't

Some natural philosophers Suppose that these colours arise from the accidental vapours diffused in the air, which communicates their own hues to the shadow

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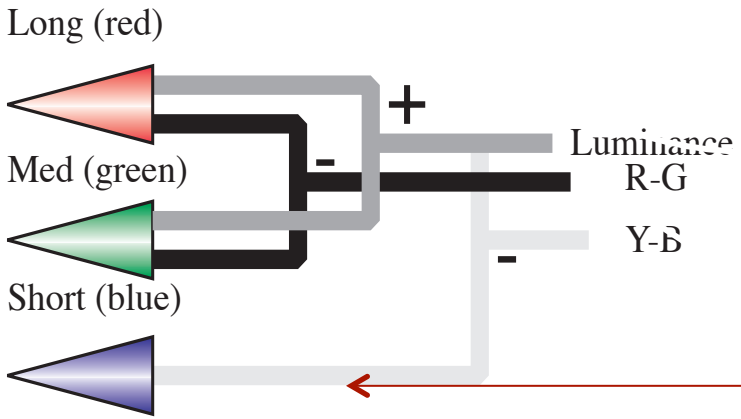
- Information Labeling: Hue works well!

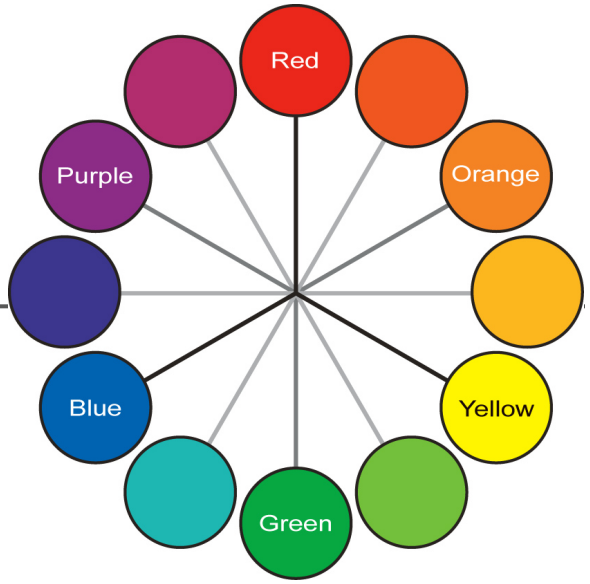
Opponent Process Theory

- Cone signals transformed into new channels
  - Black/White (Luminance; ignores blue)
  - Red/Green
  - Yellow/Blue

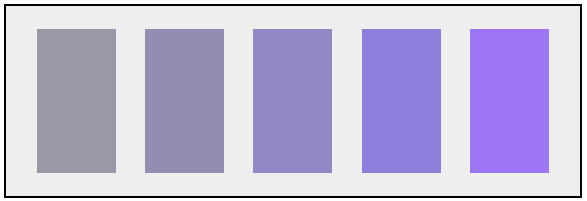
Yet another reason not to use blue to indicate the shapes of objects; it seems to be ignored in the Luminance calculation.



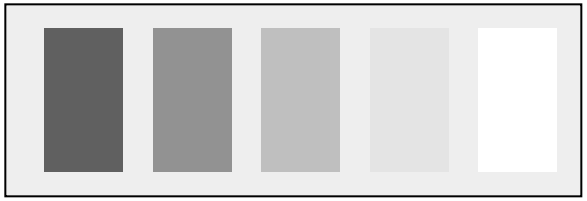
Color Design Terminology



- Hue (color wheel)
  - Red, yellow, blue (primary)
  - Orange, green, purple (secondary)
  - Opposites complement (contrast)
  - Adjacent are analogous
  - Many different color wheels*
- *See www.handprint.com for examples



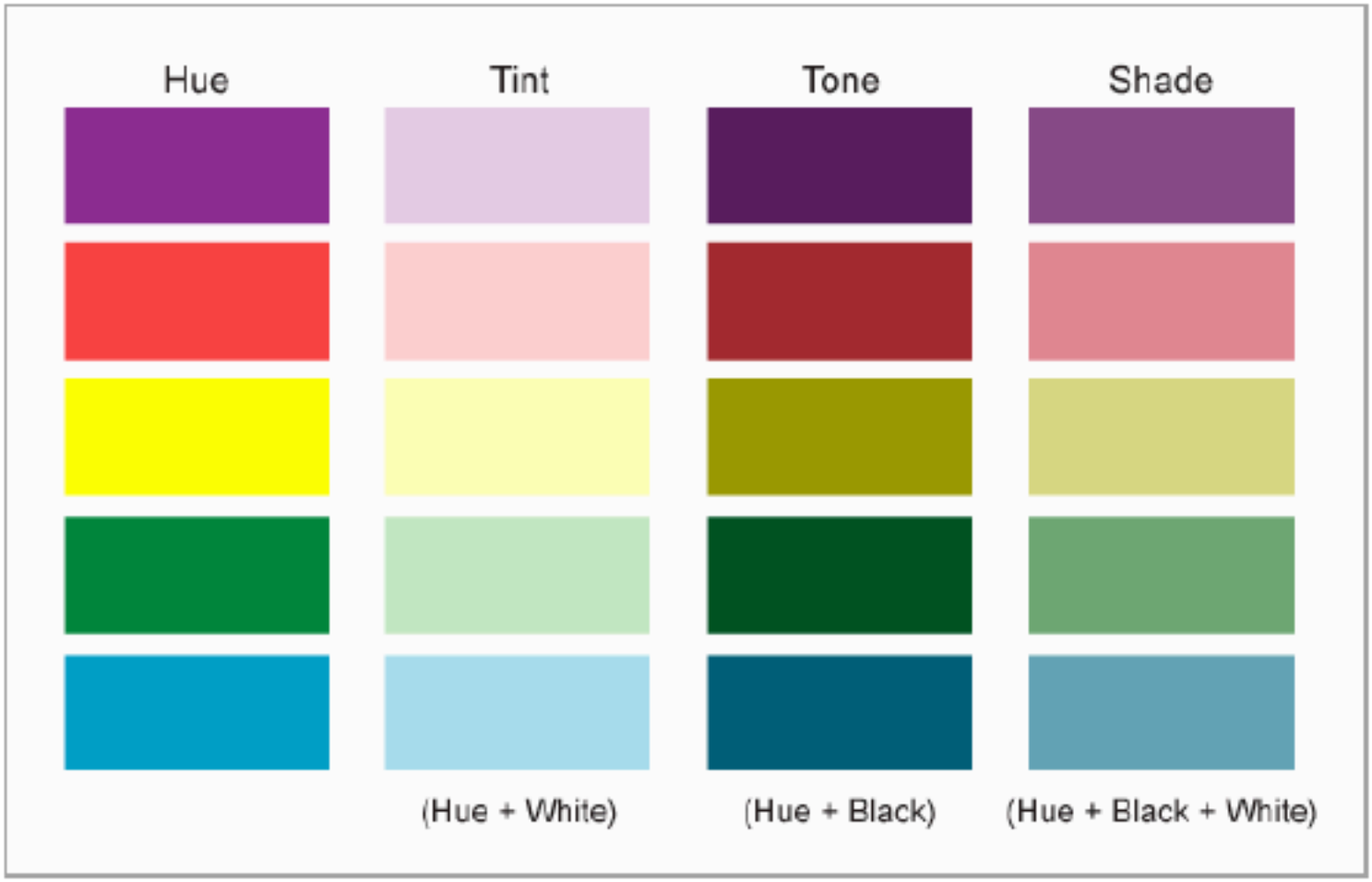
- Chroma (saturation)
  - Intensity or purity
  - Distance from gray



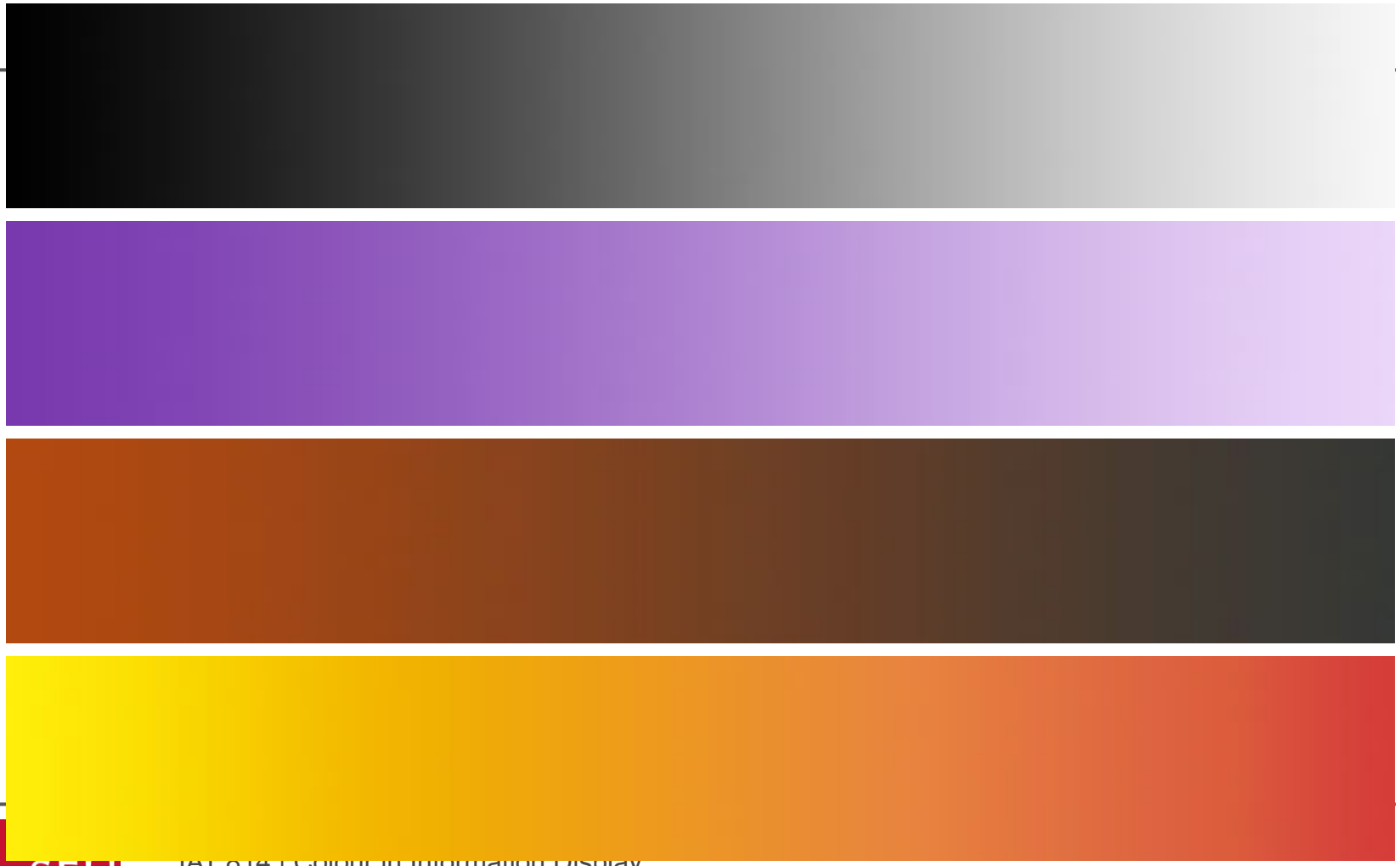
- Value (lightness)
  - Dark to light
  - Applies to all colors, not just gray

Tints and Tones

- **Tone** or shade
  - Hue + **black**
  - Decrease saturation
  - **Decrease** lightness
- **Tint**
  - Hue + **white**
  - Decrease saturation
  - **Increase** lightness

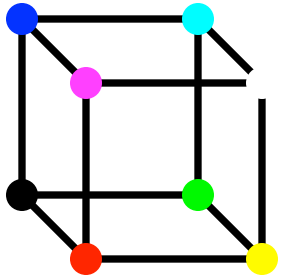

Hue
Tint
Tone
Shade
(Hue + White)
(Hue + Black)
(Hue + Black + White)

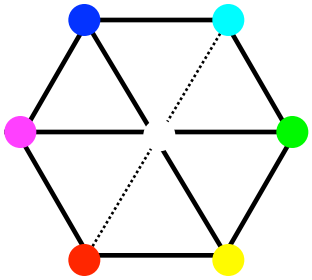
Gradations



Psuedo-Perceptual Models

- HLS, HSV, HSB
- NOT perceptual models
- Simple renotation of RGB
  - View along gray axis
  - See a hue hexagon
  - L or V is grayscale pixel value





- Cannot predict perceived lightness

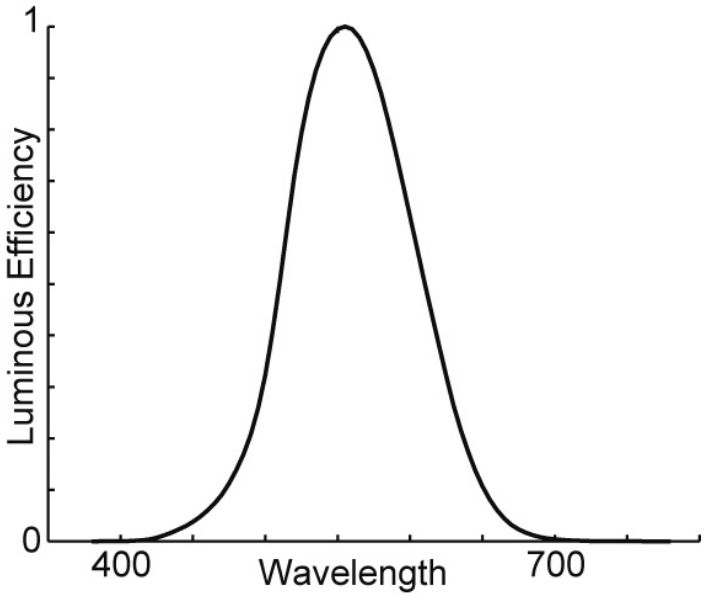
Lightness Scales

- Lightness, brightness, luminance, and L*
  - Lightness is relative, brightness absolute
  - Absolute intensity has light power as units (measured)
- Luminance is perceived intensity
  - Luminance varies with wavelength
  - Variation defined by luminous efficiency function
- L* is perceptually uniform lightness
- **Perceptual uniformity**: equal spatial distances define equal perceptual differences

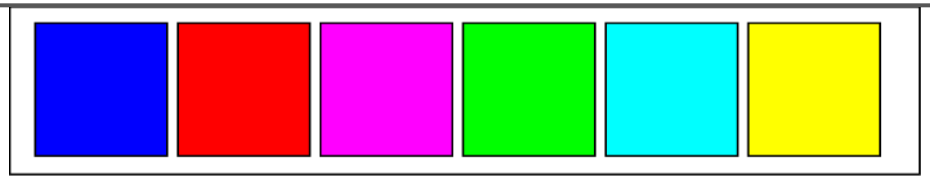
Luminance & Intensity

- Intensity
  - Integral of spectral distribution (power)
- Luminance
  - Intensity modulated by wavelength sensitivity
  - Integral of spectrum × luminous efficiency function
  - Is a **perceived** intensity

Green and blue lights of equal intensity have different luminance values

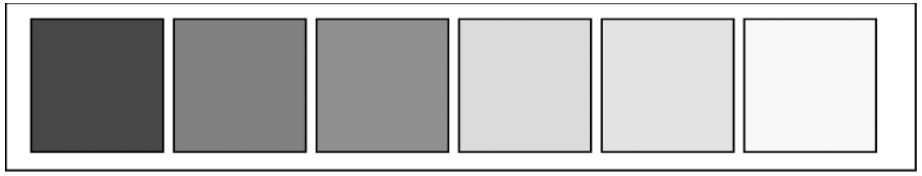


Be careful: Colour models, luminance and L*

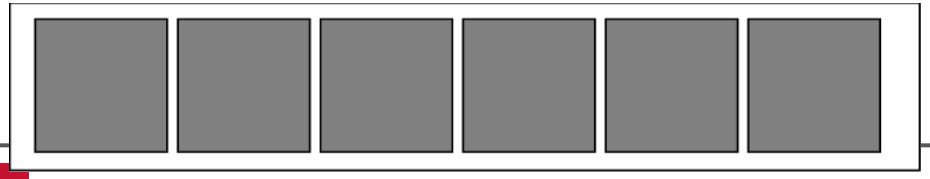


Corners of the RGB color cube

Luminance values (retinal response)



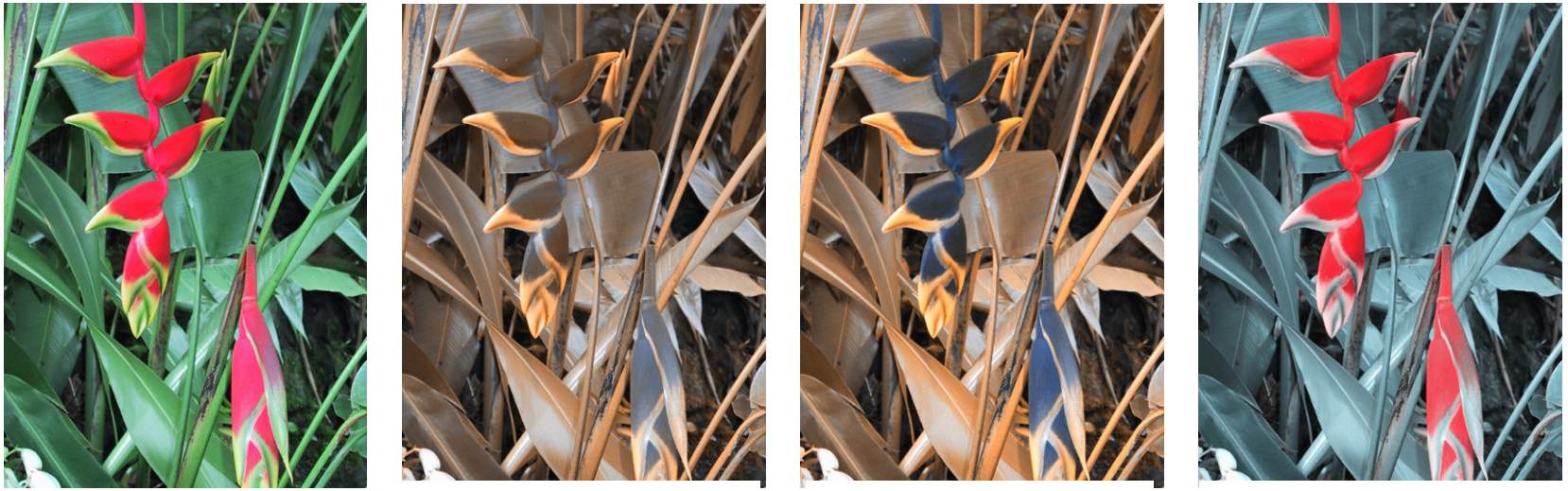
L* values



L from HLS
All the same

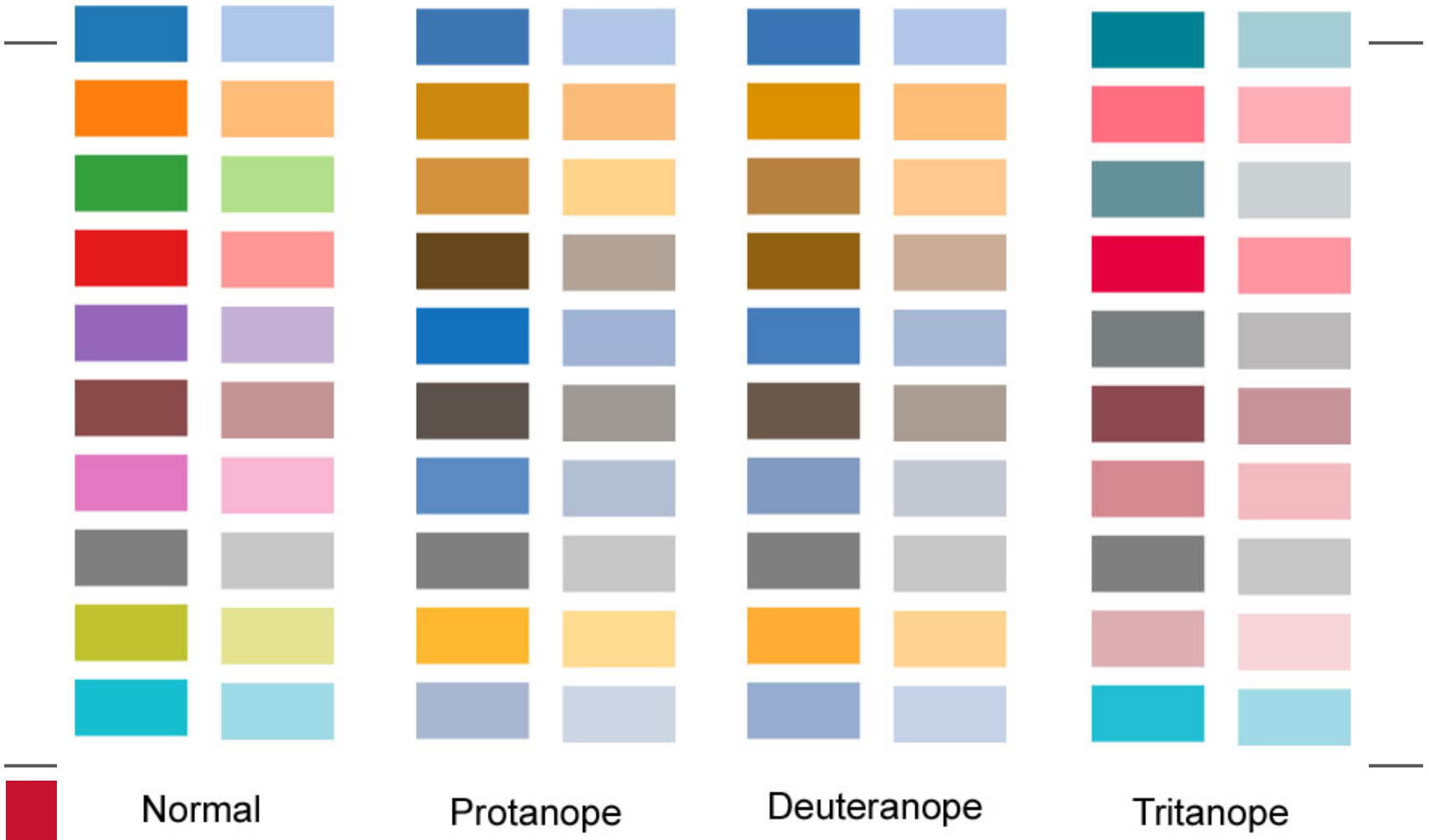
Colour Deficiency (VCD)

- Simulates color vision deficiencies
  - Photoshop plug-in (View→Proof Setup→Color Deficiency)
  - VisCheck (Robert Dougherty and Alex Wade)

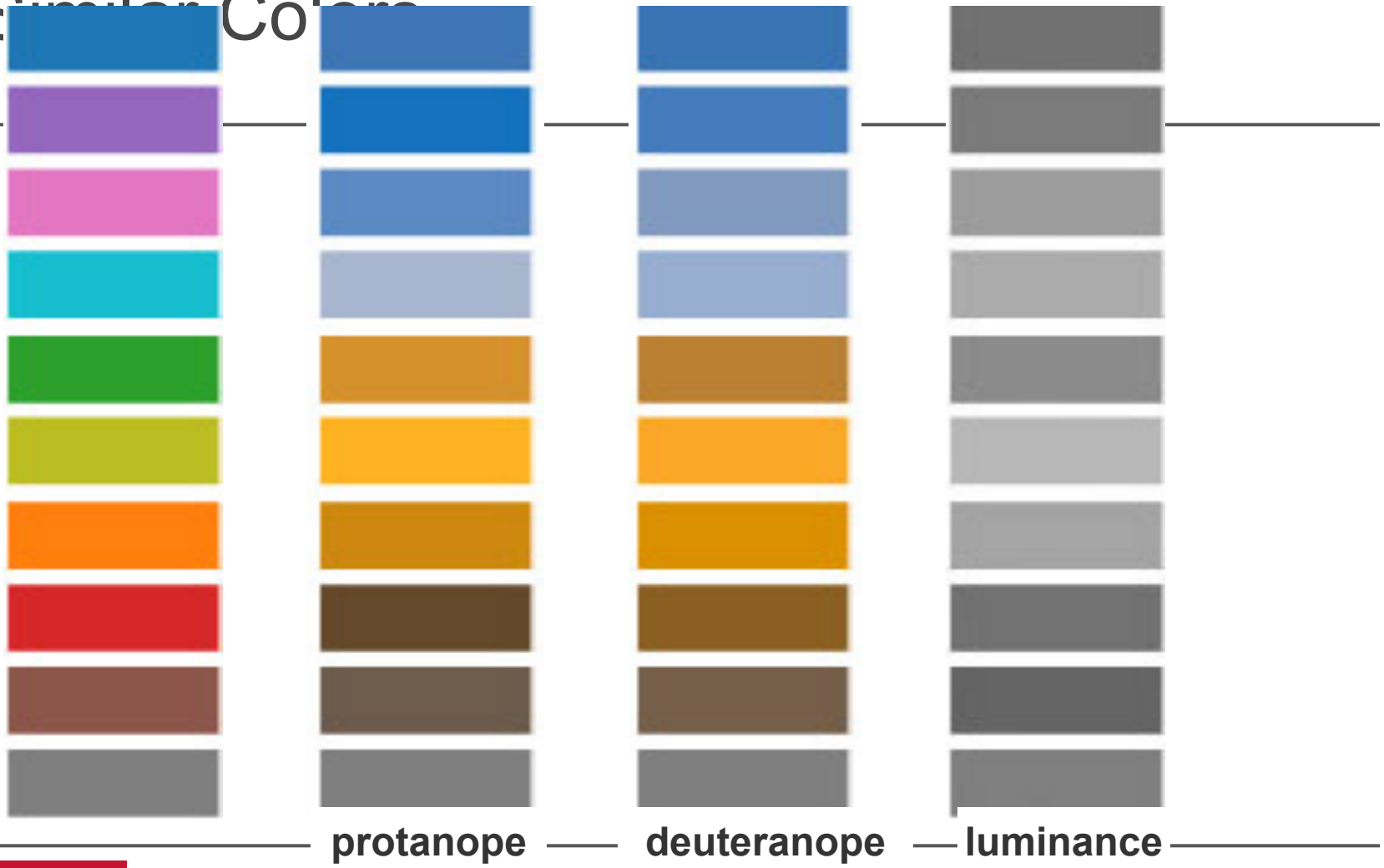


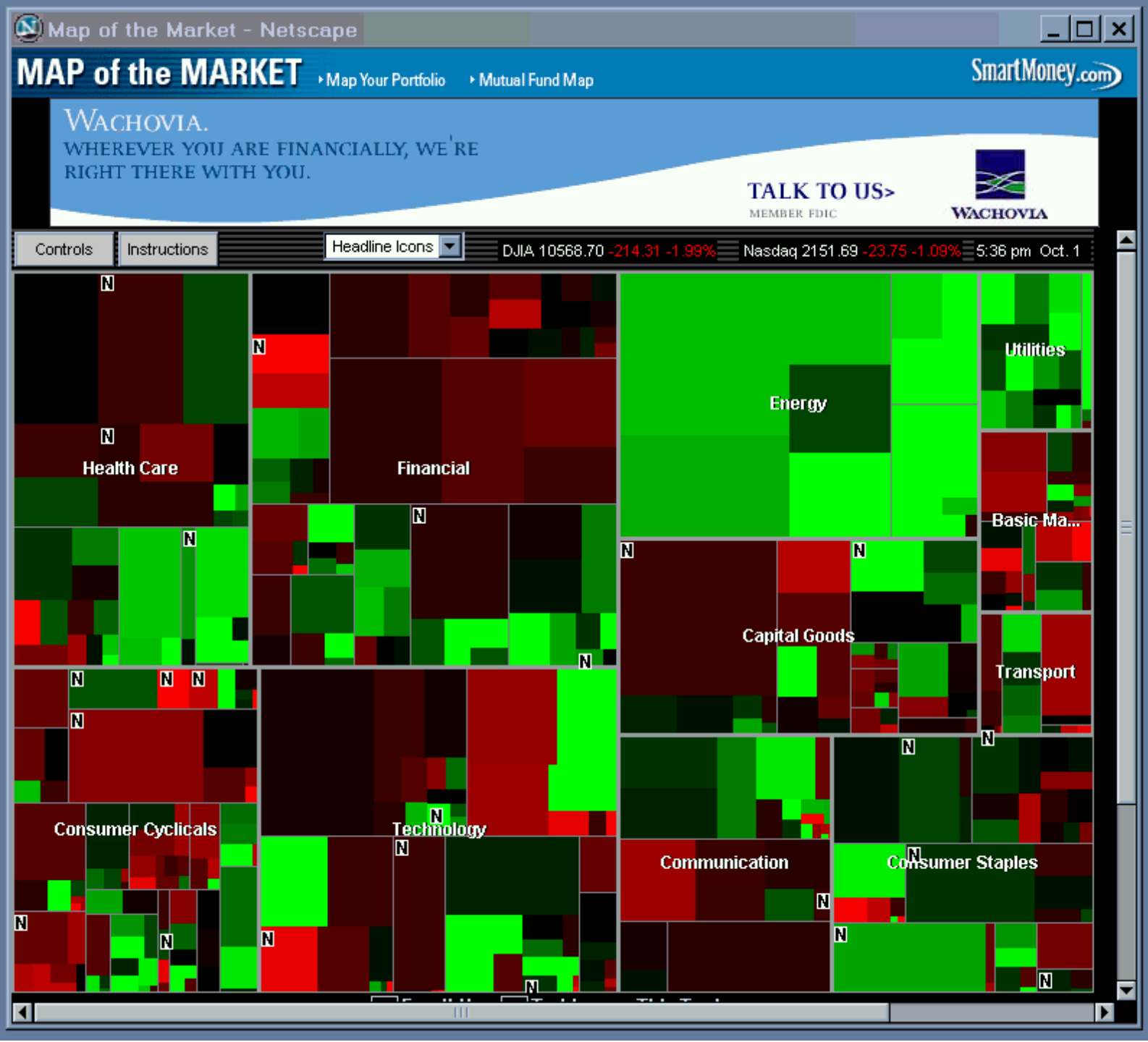
Deuteranope — Protanope — Tritanope

2D Color Space



Similar Colors




Map of the Market - Netscape
MAP of the MARKET
Map Your Portfolio
Mutual Fund Map
SmartMoney.com
WACHOVIA.
WHEREVER YOU ARE FINANCIALLY, WE'RE RIGHT THERE WITH YOU.
TALK TO US>
MEMBER FDIC
WACHOVIA
Controls
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Headline Icons
DJIA 10568.70 -214.31 -1.99%
Nasdaq 2151.69 -23.75 -1.09%
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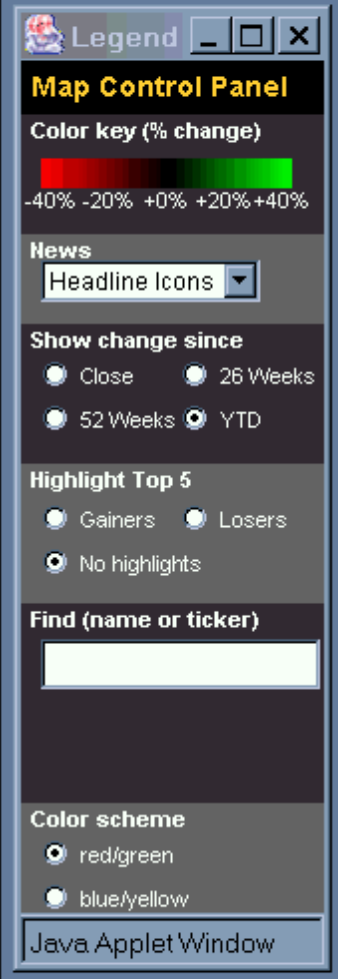
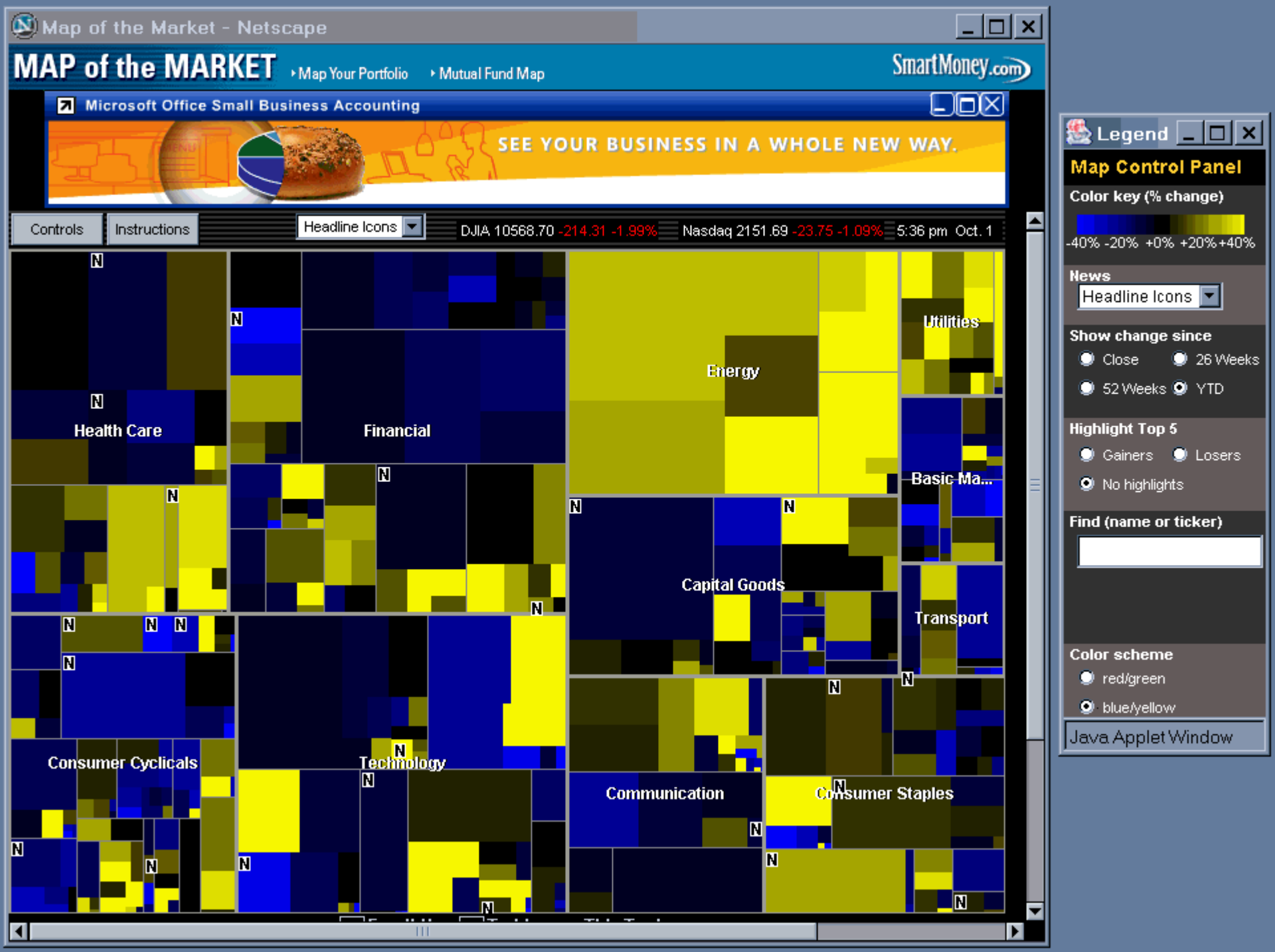
Communication
Consumer Staples


Legend
Map Control Panel
Color key (% change)
-40% -20% +0% +20% +40%
News
Headline Icons
Show change since
Close
26 Weeks
52 Weeks
YTD
Highlight Top 5
Gainers
Losers
No highlights
Find (name or ticker)
Color scheme
red/green
blue/yellow
Java Applet Window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Color Appearance

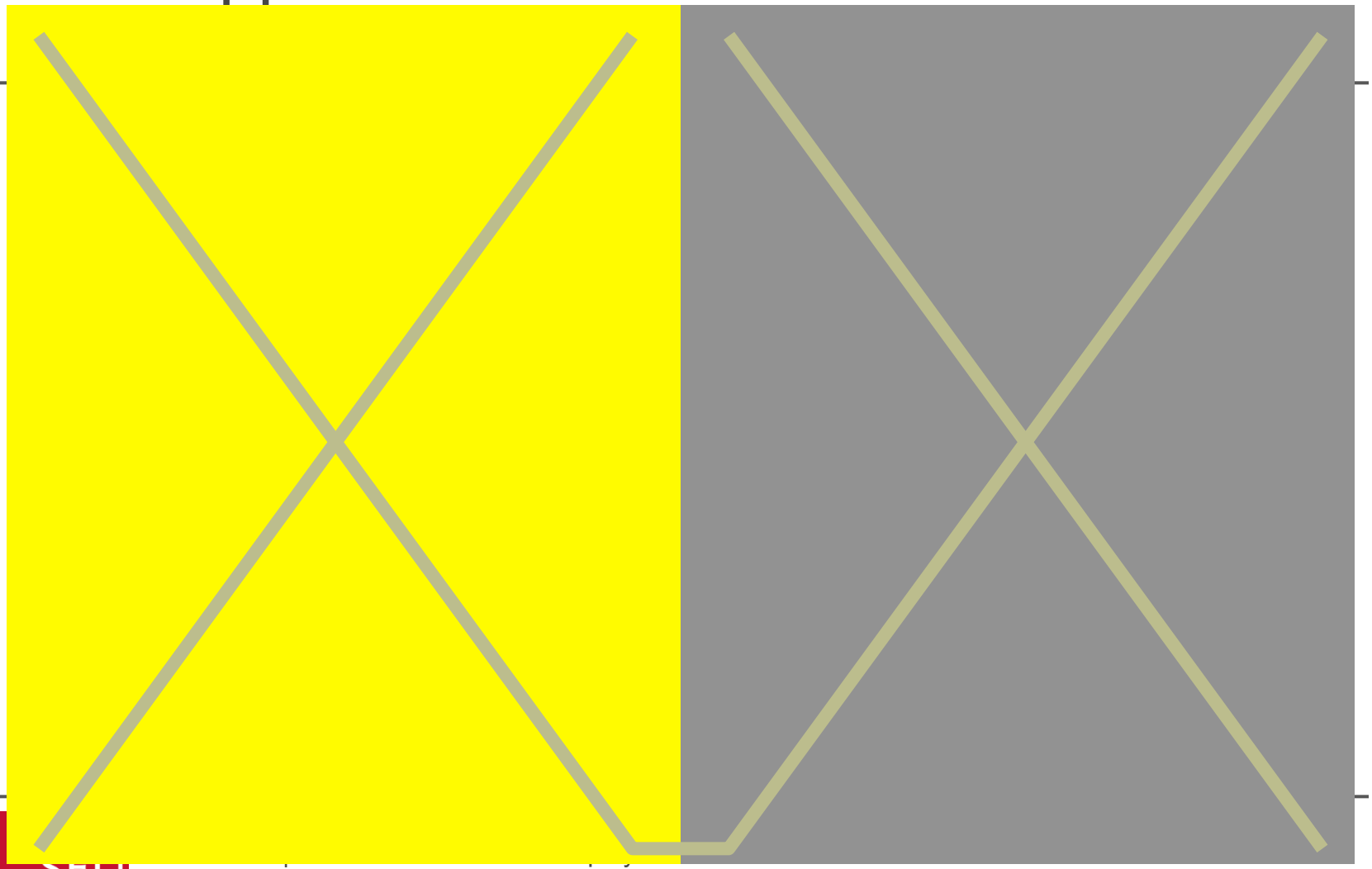

Image courtesy of John MCann

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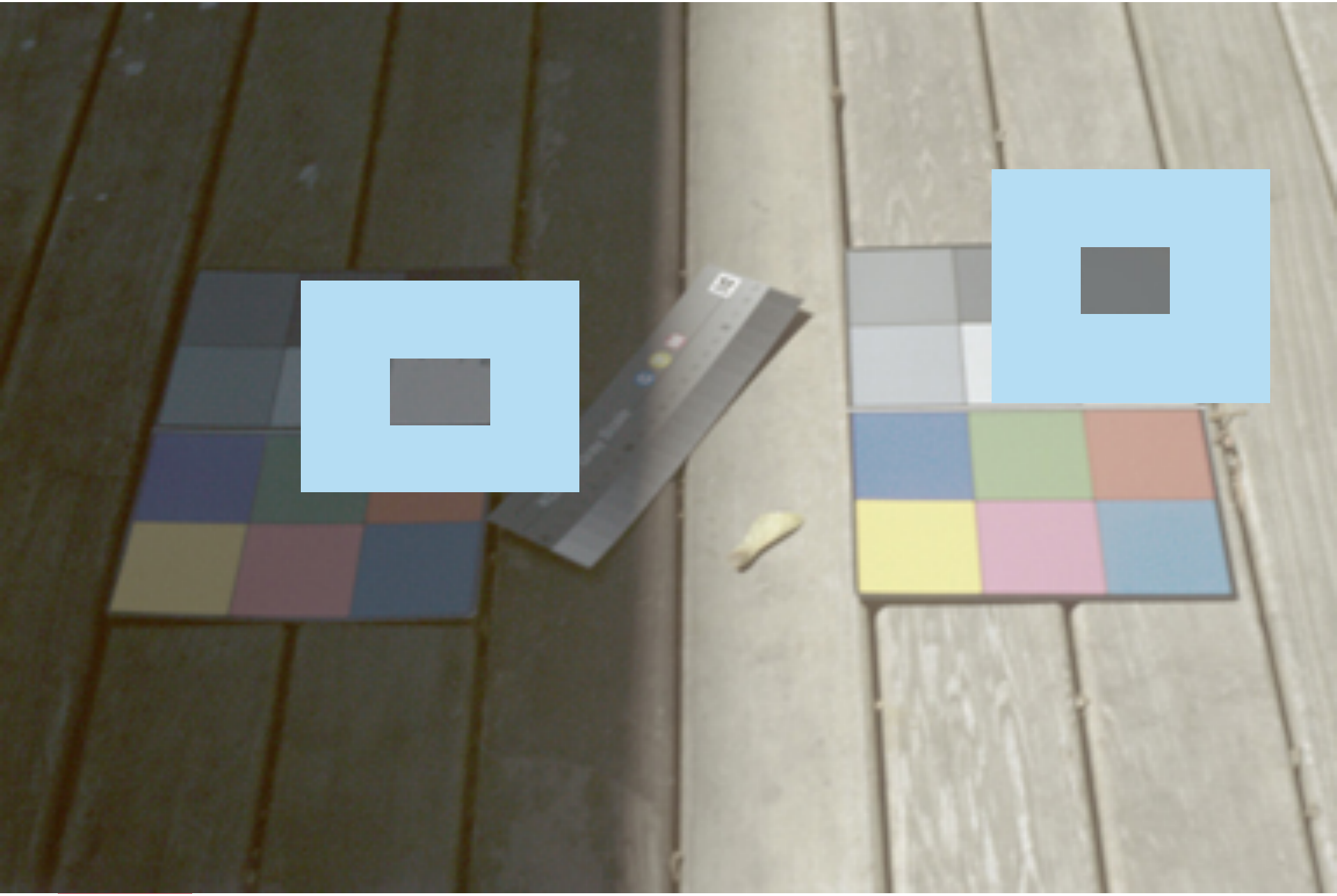
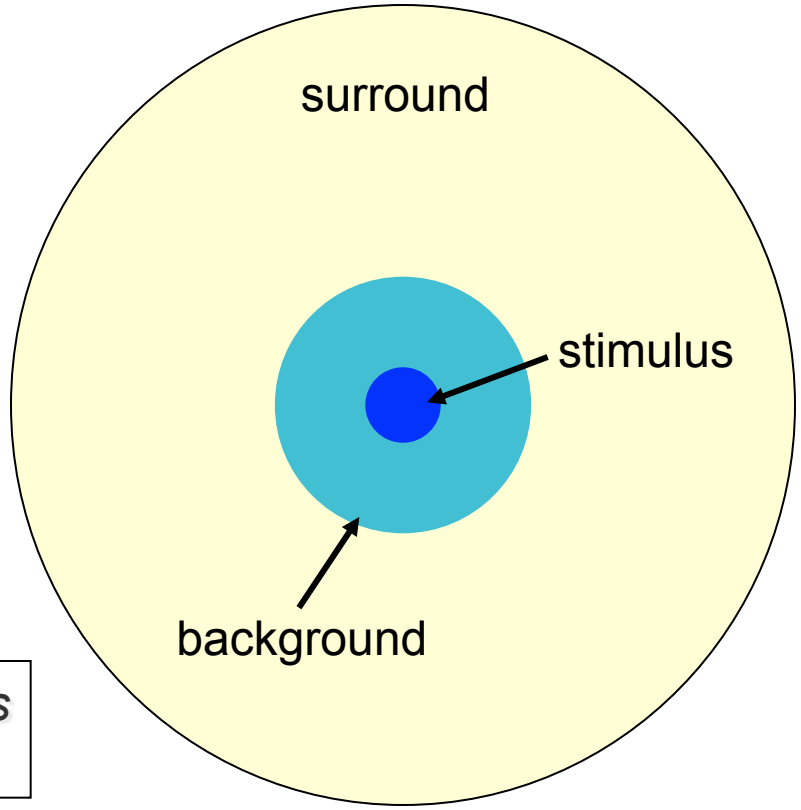


Color Appearance

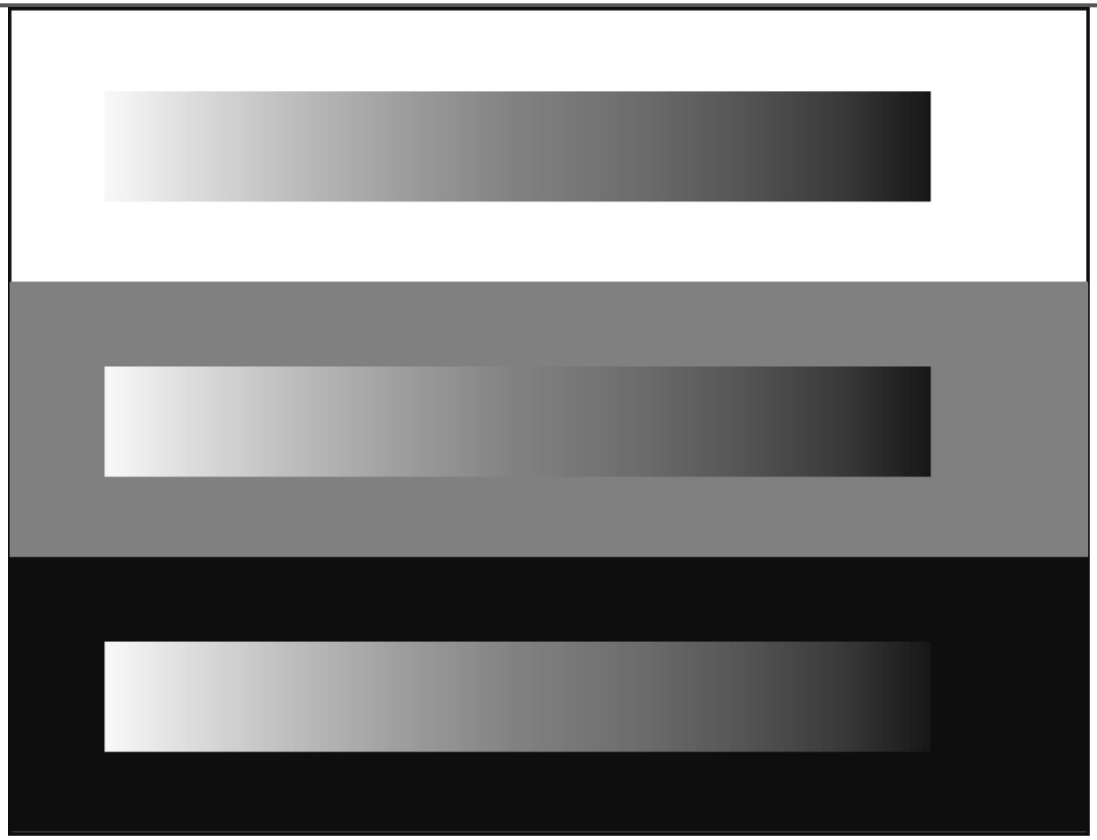
- More than a single color
  - Adjacent colors (background)
  - Viewing environment (surround)
- Appearance effects
  - Adaptation
  - Simultaneous contrast
  - Spatial effects
- Color in context



Color Appearance Models
Mark Fairchild

Simultaneous contrast

Affects Lightness Scale

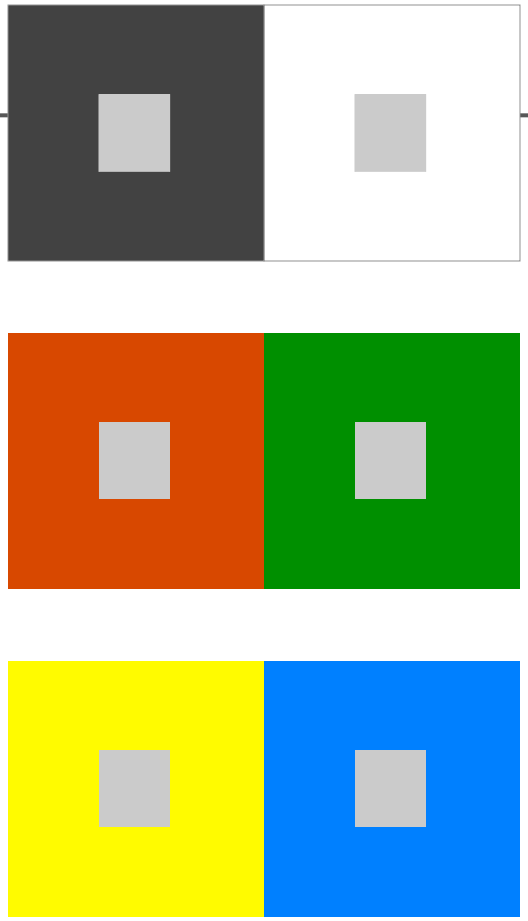


Simultaneous Contrast

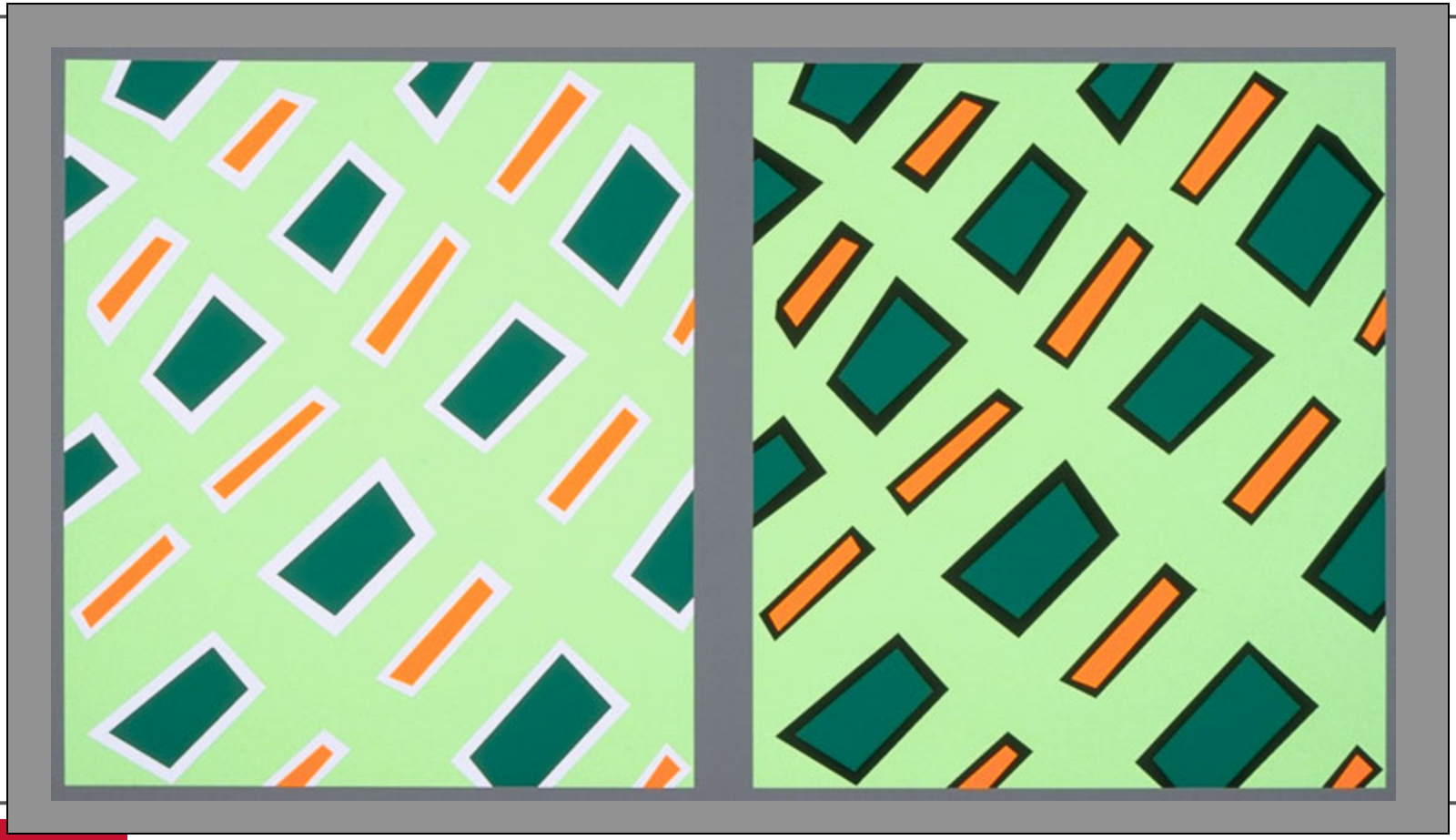
- Influence of immediate surround on perception of colour

- Simple example:
- Add Opponent Color
  - Dark adds light
  - Red adds green
  - Blue adds yellow

These samples will have both light/ dark and hue contrast

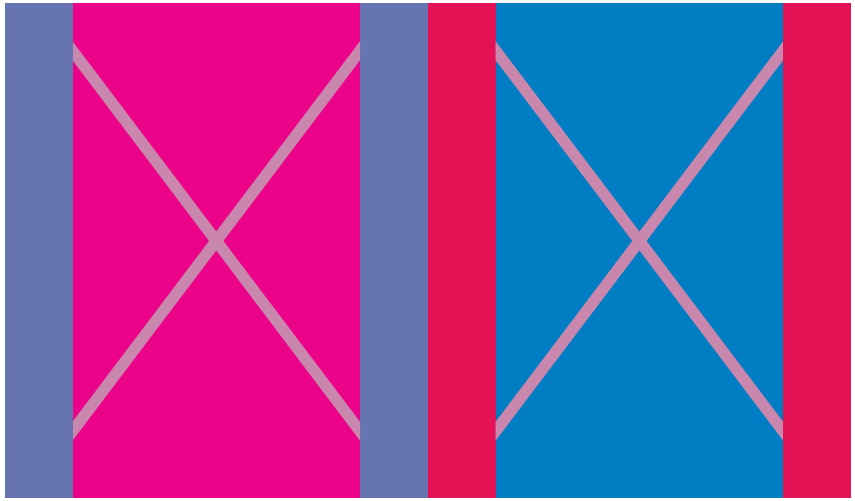


Bezold Effect: outline makes a difference

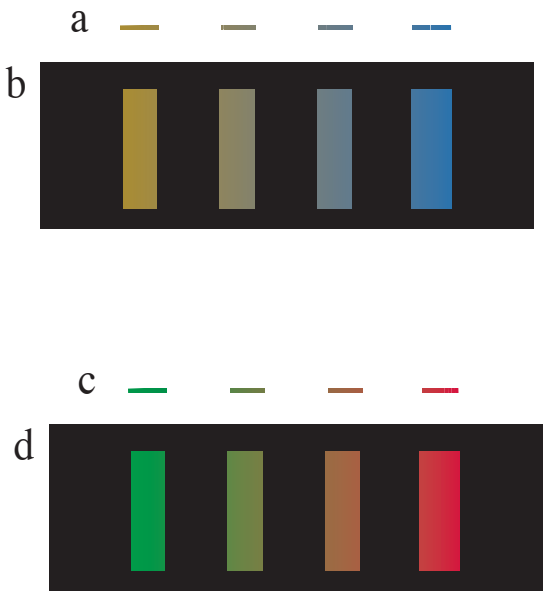


Other contrast effects

Chromatic contrast

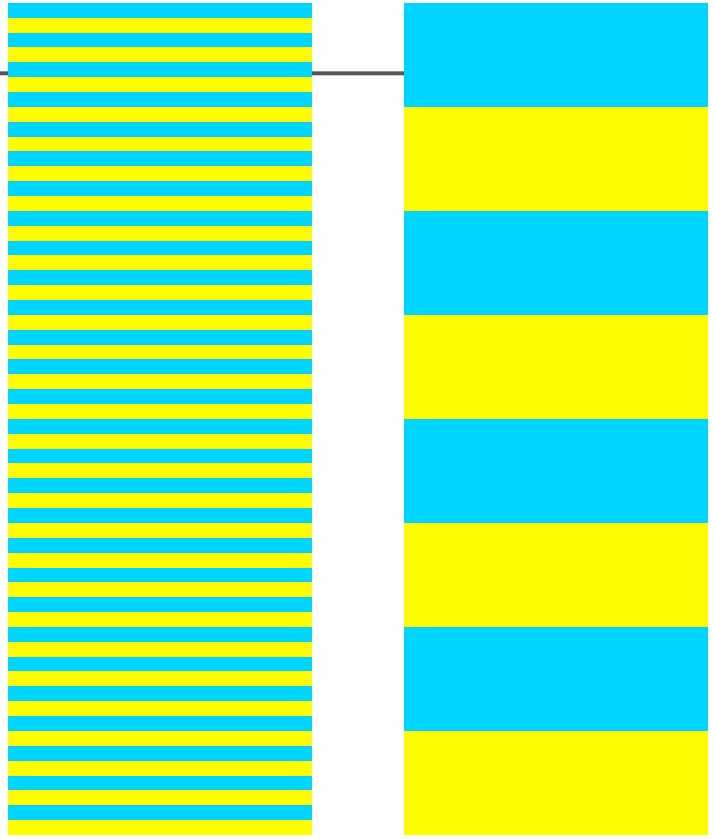


Small field tritanopia



Spreading

- Spatial frequency
  - The paint chip problem
  - Small text, lines, glyphs
  - Image colors
- Adjacent colors blend
- The higher the spatial frequency, the less saturated the colour



Redrawn from *Foundations of Vision*
© Brian Wandell, Stanford University

Coding with Colour

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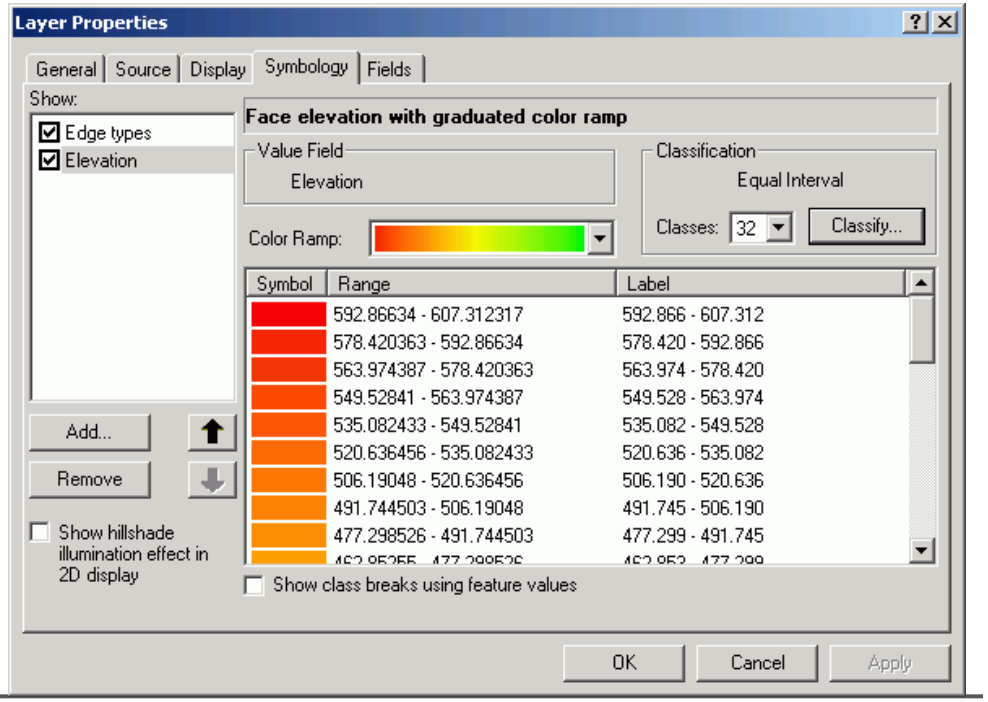
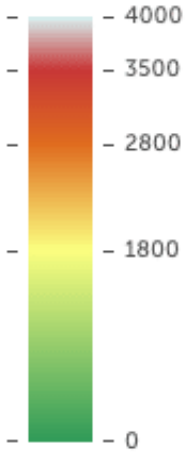
What makes color effective?

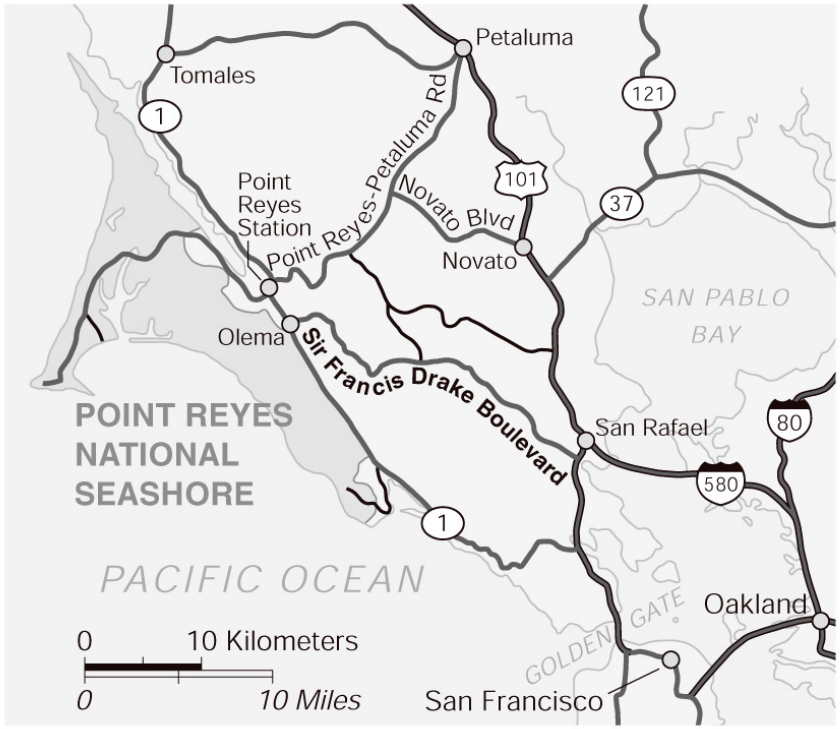


"Good ideas executed with superb craft"

—*E.R. Tufte*



Information Display

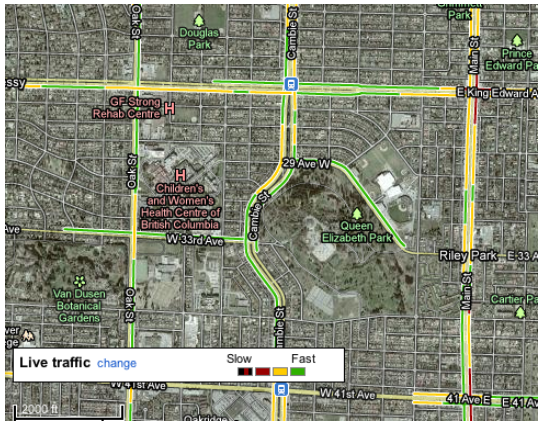


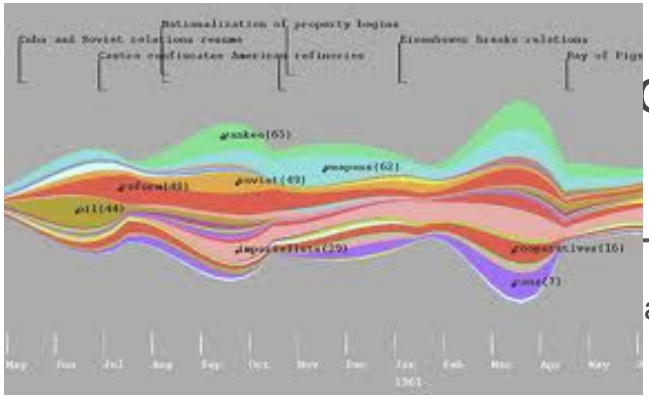
Colour includes Grey

www.nps.gov

A quick revisit of data characteristics

- What kind of task are you hoping to support?
- What kind of data do you have?
- No single approach





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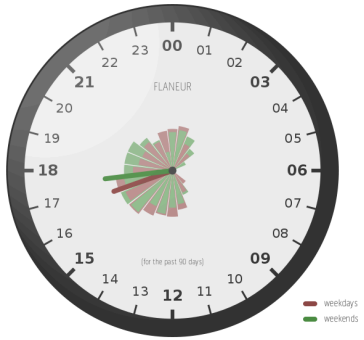


ation Display

Data types: recap

- **Nominal**: names without ordering
  - Continents: Africa, America, Asia, Australia, Europe
  - No concept of relative relationship other than inclusion in the set

- **Ordinal**: Before-than than relationship holds
  - Rental cars: Economy, Compact, Mid-sized, Full-sized
  - Distance is not uniform

- **Quantitative**: Relative measurements, equal distances, numeric

Color Design Principles

- Control value (lightness)
  - Ensure legibility
  - Avoid unwanted emphasis
- Use a limited hue palette
  - Control color “pop out”
  - Define color grouping
  - Avoid clutter from too many competing colors
- Use neutral backgrounds
  - Control impact of color
  - Minimize simultaneous contrast

Envisioning Information

"… avoiding catastrophe becomes the first principle in bringing color to information:

Above all, do no harm."

—E. R. Tufte

www.edwardtufte.com

Encoding data with colour

- Data Types
  - Nominal, ordinal, quantitative
  - Qualitative, sequential, diverging
- colour scales
  - Hue scale
    - Nominal (labels)
    - Cyclic (learned order)
  - Lightness or saturation scales
    - Ordered scales
    - Lightness best for high frequency
    - More = darker (or more saturated)
    - Most accurate if *quantized*

Quantized
- Signal varies continuously

Discretized
- Restricted to a prescribed set of values

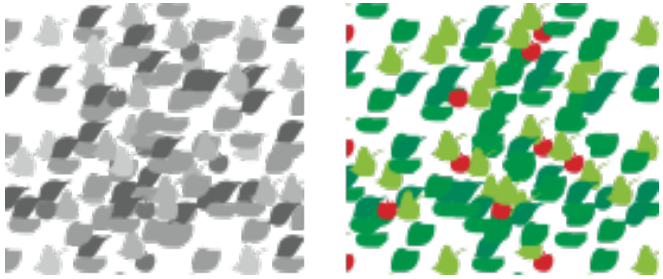
Fundamental Uses

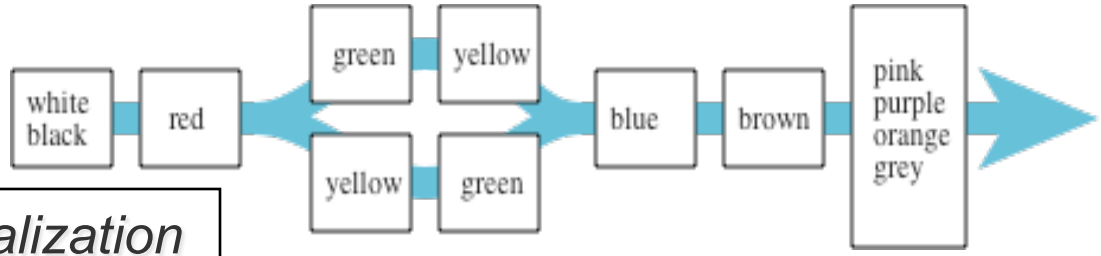
- To label (colour as **noun**)
- To measure (colour as **quantity/value**)
- To represent (colour as **representation**)
  - to imitate reality
- To enliven or decorate (colour as **beauty**)

To Label
(nominal coding)

Colour great for classification

- Rapid visual segmentation
- Colour helps us determine type
- Only about six categories

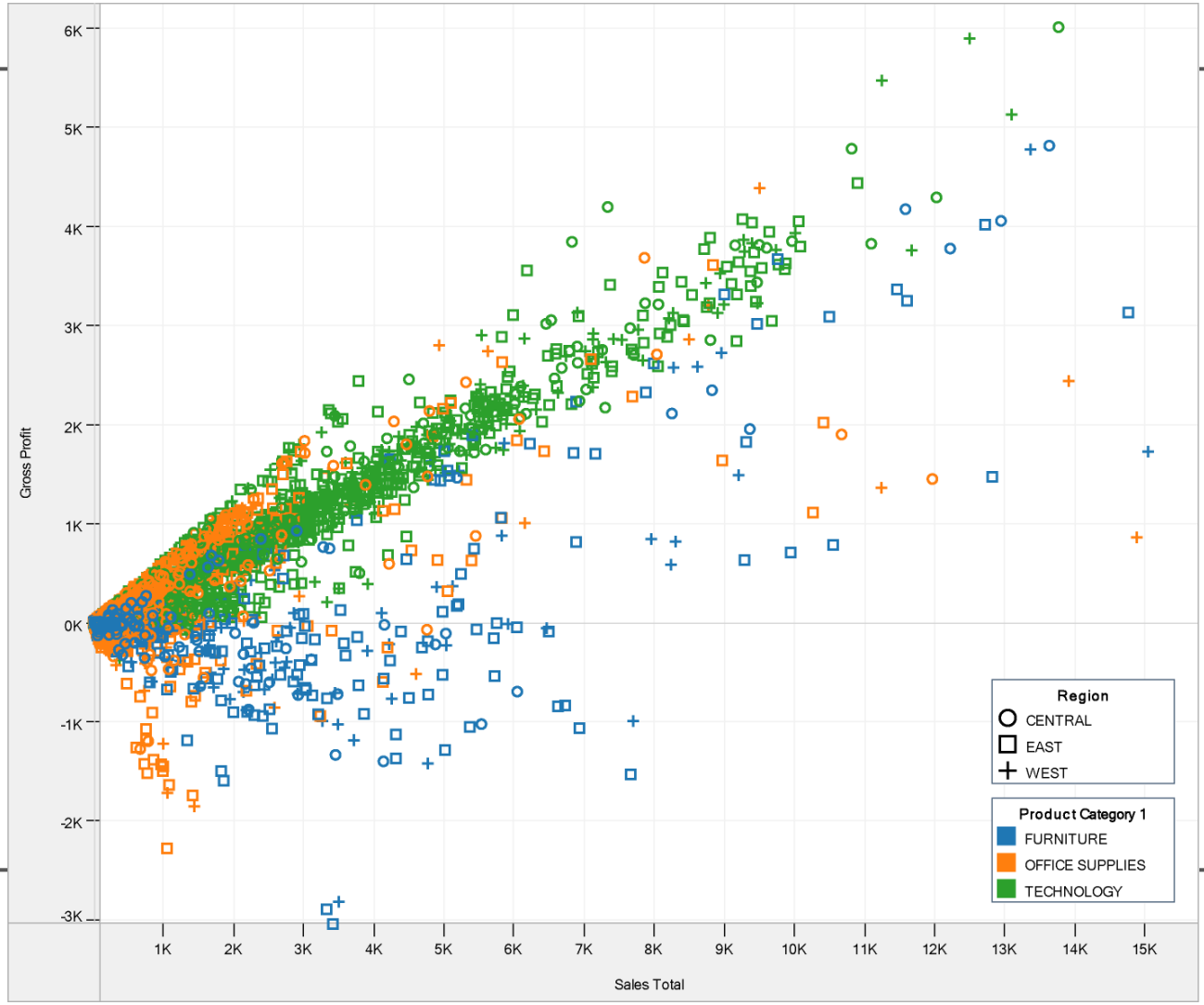




Information Visualization
Colin Ware

Product Categories

Created by Tableau - Visual Analysis for Databases™



SFU

Grouping, Highlighting

	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
red	25.37	13.70	0.05	26.27	14.13	0.04	18.41	10.16	0.05	17.43	9.30	0.00
green	22.14	51.24	0.35	20.68	49.17	0.44	21.11	46.00	0.20	16.36	37.95	0.12
blue	13.17	3.71	74.89	15.38	5.20	86.83	11.55	3.37	65.53	9.96	3.44	56.14
gray	63.46	73.30	78.05	64.66	71.99	90.08	52.96	62.49	67.99	45.54	53.65	58.14
black	0.66	0.70	0.77	0.63	0.66	1.09	0.47	0.58	0.70	0.44	0.54	0.71

	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
red	25.37	13.70	0.05	26.27	14.13	0.04	18.41	10.16	0.05	17.43	9.30	0.00
green	22.14	51.24	0.35	20.68	49.17	0.44	21.11	46.00	0.20	16.36	37.95	0.12
blue	13.17	3.71	74.89	15.38	5.20	86.83	11.55	3.37	65.53	9.96	3.44	56.14
gray	63.46	73.30	78.05	64.66	71.99	90.08	52.96	62.49	67.99	45.54	53.65	58.14
black	0.66	0.70	0.77	0.63	0.66	1.09	0.47	0.58	0.70	0.44	0.54	0.71

Considerations for Labels (N)

- How critical is the color encoding?
  - Unique specification or is it a “hint”?
  - Quick response, or time for inspection?
  - Is there a legend, or need it be memorized?
- Contextual issues
  - Are there established semantics?
  - Grouping or ordering relationships?
  - Surrounding shapes and colors?
- Shape and structural issues
  - How big are the objects?
  - How many objects, and could they overlap?
  - Need they be readable, or only visible (discernible)?

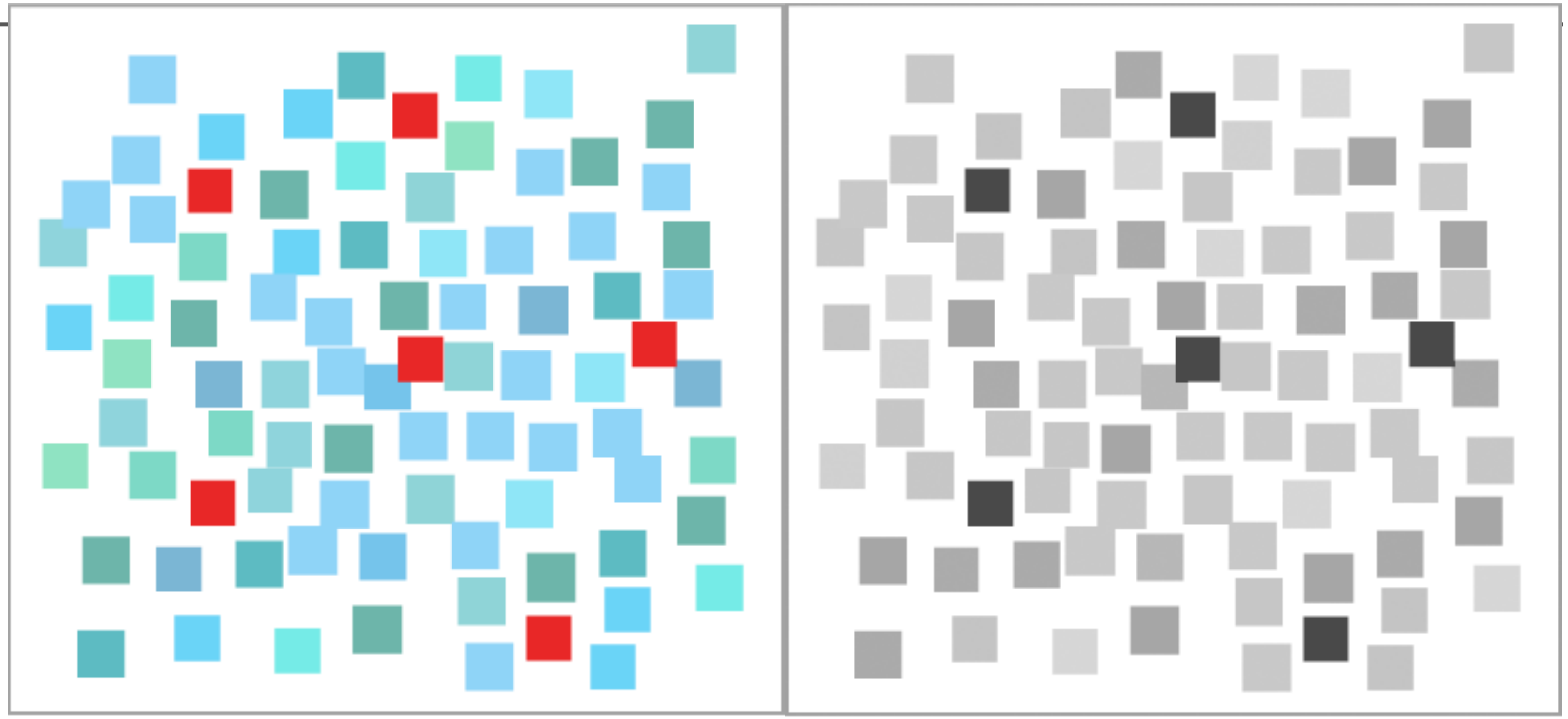
Psychophysics of Labeling

- Preattentive, “pop

1357934597827405 5
2493791647825413 7
2387659727710386 6
1987436725904736 2
9563728364910567 6
3254378795483675 4
5684037846548569 0

Time proportional to the number of digits

Contrast Creates Pop-out

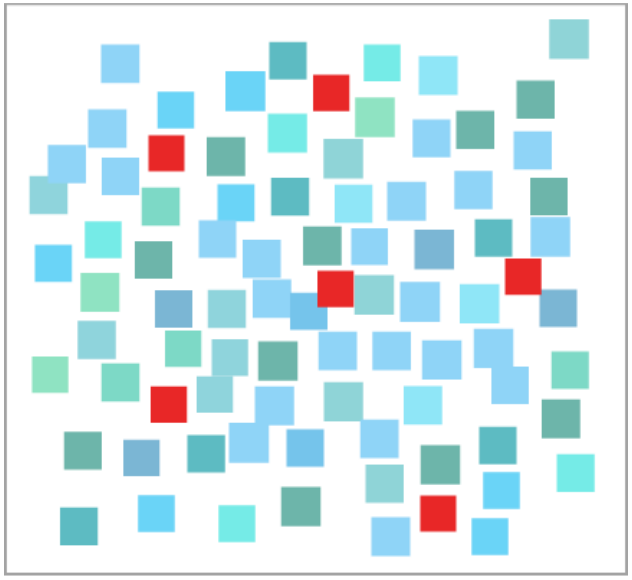


Hue and lightness

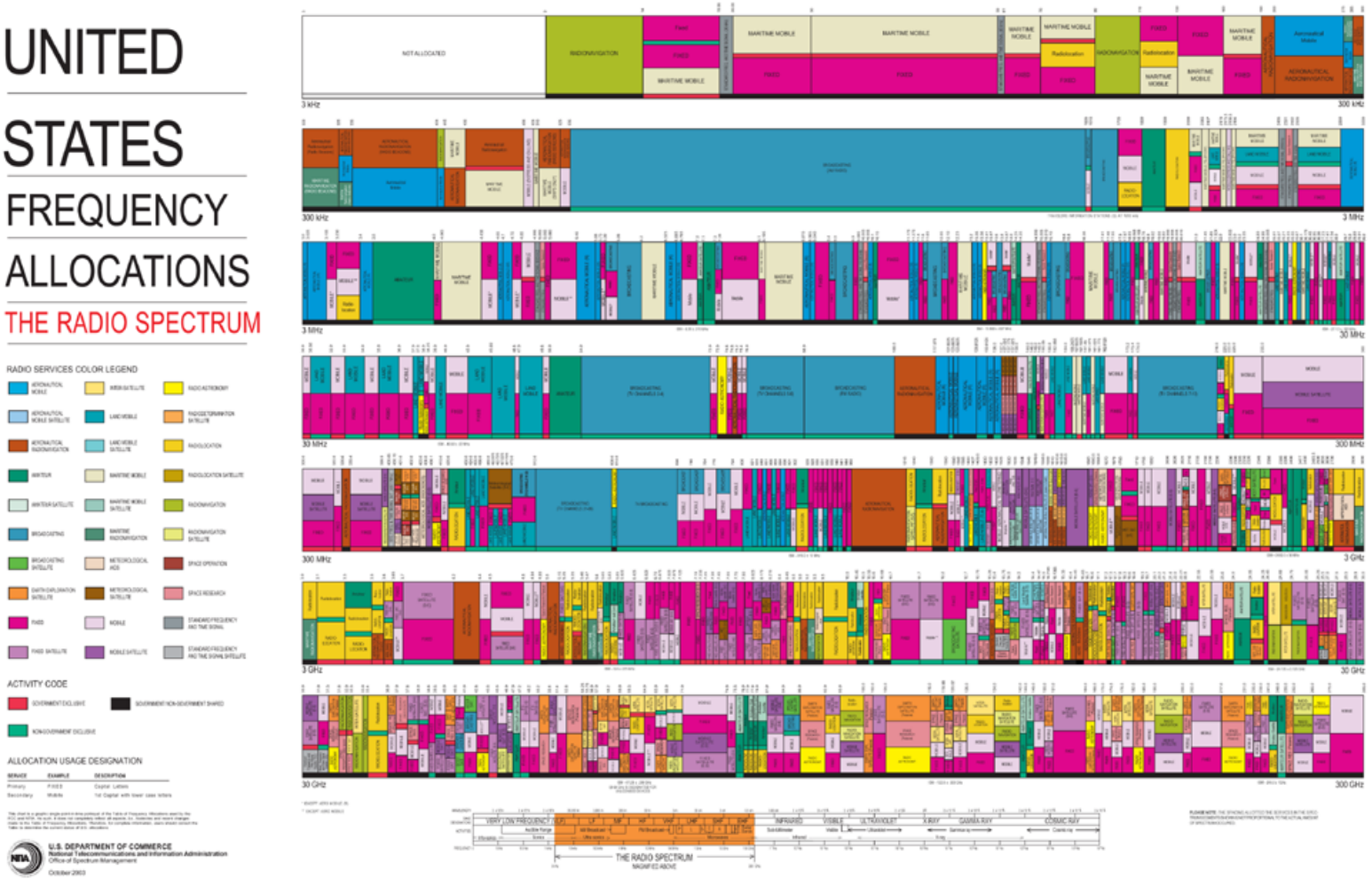
Lightness only

Pop-out vs. Distinguishable

- Pop-out
  - Typically, 5-6 distinct values simultaneously
  - Up to 9 under controlled conditions
- Distinguishable
  - 20 easily for reasonable sized stimuli
  - More if in a controlled context
  - Usually need a legend



Radio Spectrum Map (33 colors)



http://www.cybergeography.org/atlas/us_spectrum_map.pdf

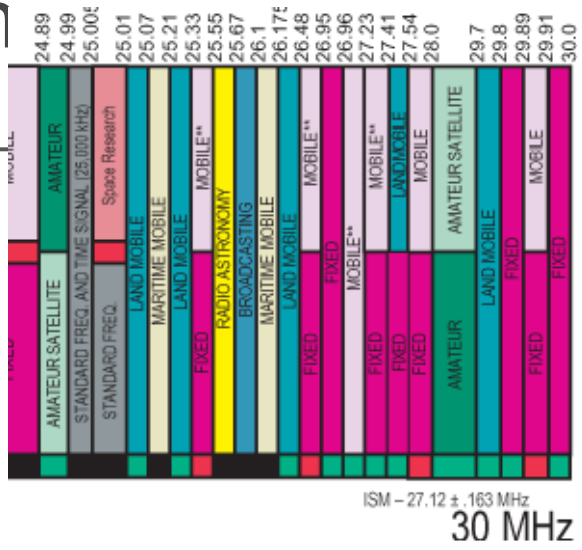
Distinguishable on Inspection

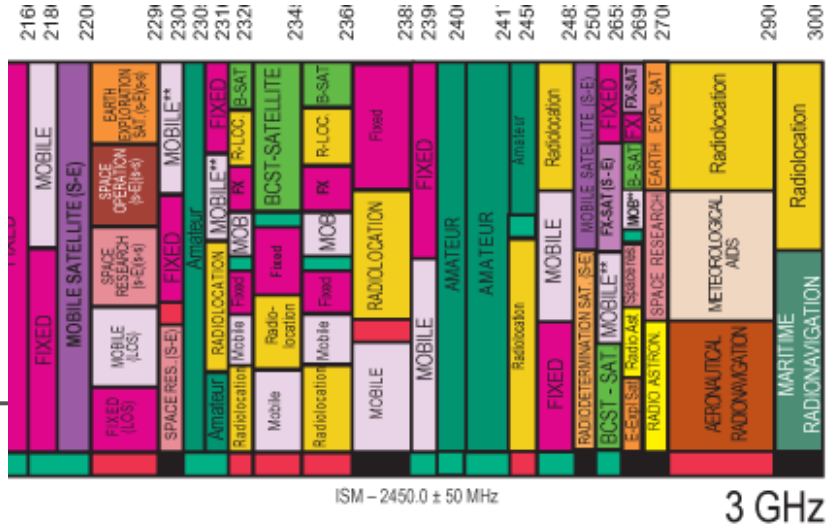
RADIO SERVICES COLOR LEGEND

- AERONAUTICAL MOBILE
- AERONAUTICAL MOBILE SATELLITE
- AERONAUTICAL RADIONAVIGATION
- AMATEUR
- AMATEUR SATELLITE
- BROADCASTING
- BROADCASTING SATELLITE
- EARTH EXPLORATION SATELLITE
- FIXED
- FIXED SATELLITE
- INTER-SATELLITE
- LAND MOBILE
- LAND MOBILE SATELLITE
- MARITIME MOBILE
- MARITIME MOBILE SATELLITE
- MARITIME RADIONAVIGATION
- METEOROLOGICAL AIDS
- METEOROLOGICAL SATELLITE
- MOBILE
- MOBILE SATELLITE
- RADIO ASTRONOMY
- RADIODETERMINATION SATELLITE
- RADIOLOCATION
- RADIOLOCATION SATELLITE
- RADIONAVIGATION
- RADIONAVIGATION SATELLITE
- SPACE OPERATION
- SPACE RESEARCH
- STANDARD FREQUENCY AND TIME SIGNAL
- STANDARD FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

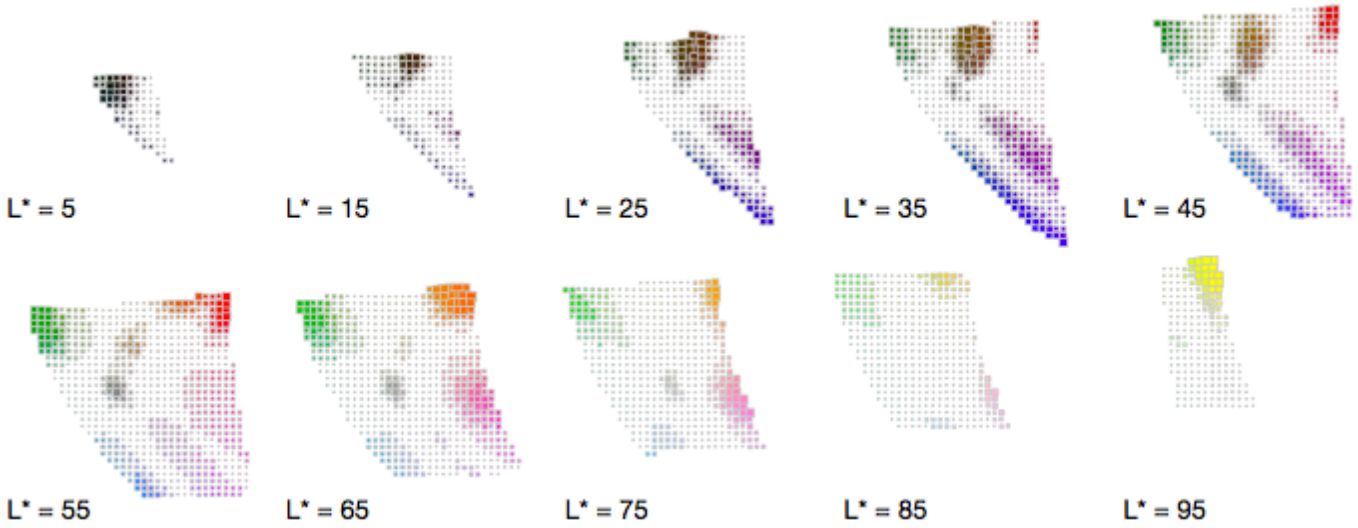
- GOVERNMENT EXCLUSIVE
- GOVERNMENT/ NON-GOVERNMENT SHARED
- NON-GOVERNMENT EXCLUSIVE





Colour naming is constant

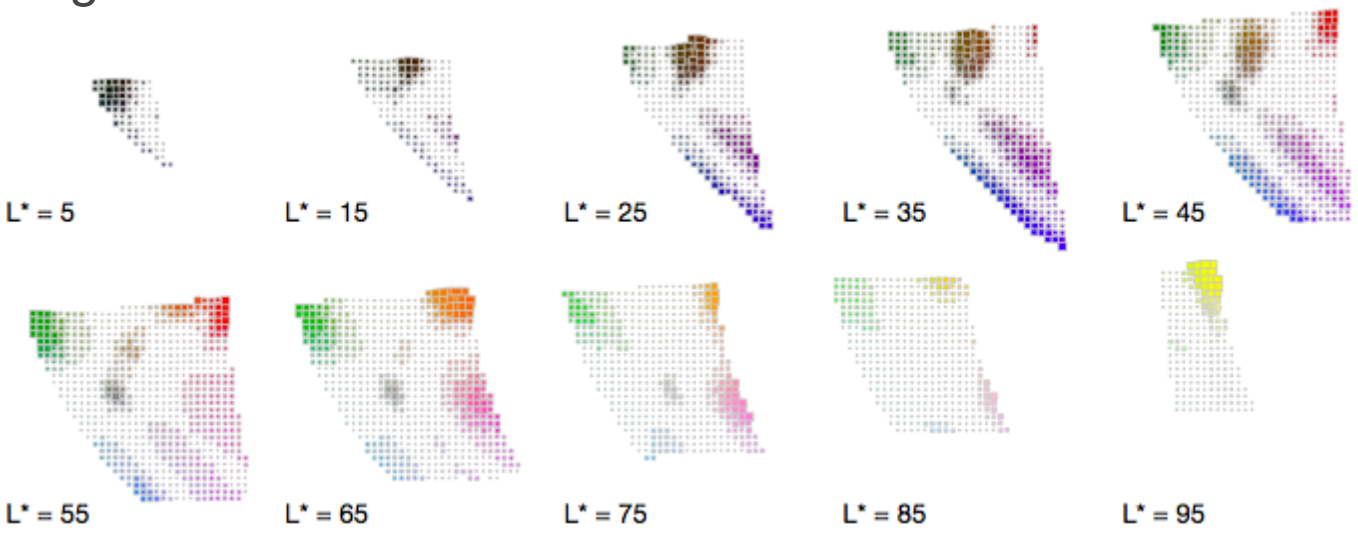
- Consistent set of colour names [Berlin & Kay]:
  - blue, brown, green, orange, pink, purple, red, yellow, black, grey, white



Jeffrey Heer and Maureen Stone. 2012. Color naming models for color selection, image editing and palette design. In Proceedings of CHI '12. ACM, New York, NY, USA, 1007-1016

Colour naming is constant

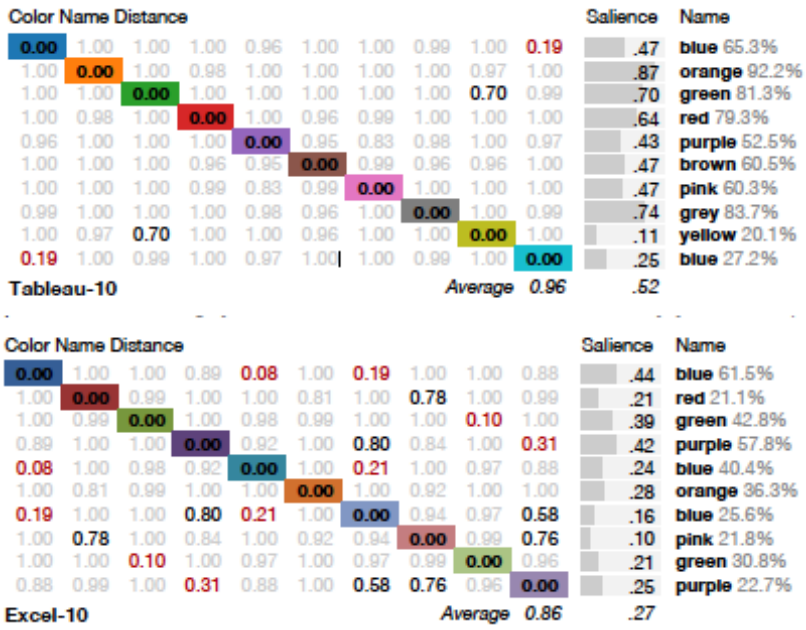
- Differences (salience) are not constant,
  - naming confusion between “greens” and “blues”
  - Orange and red



Jeffrey Heer and Maureen Stone. 2012. Color naming models for color selection, image editing and palette design. In Proceedings of CHI '12. ACM, New York, NY, USA, 1007-1016

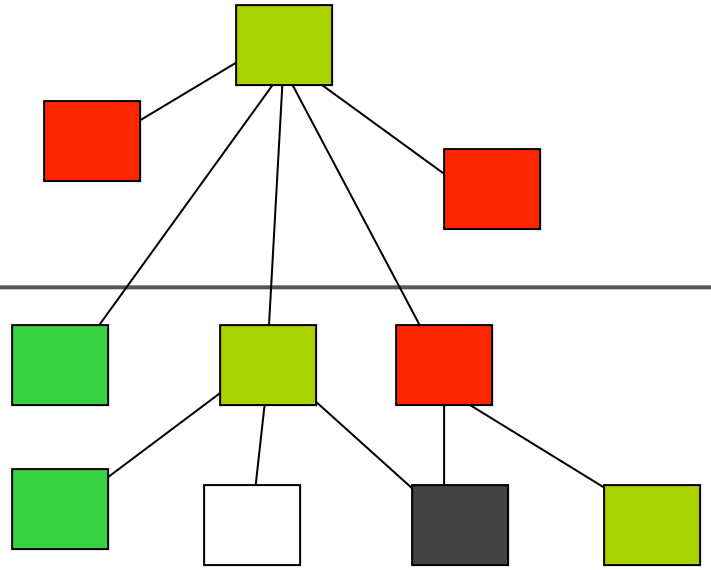
Colour palettes for nominal encoding

- Minimise name overlap
- Maximise salience
- Reduce ambiguity
- Enhance memory



Jeffrey Heer and Maureen Stone. 2012. Color naming models for color selection, image editing and palette design. In Proceedings of CHI '12. ACM, New York, NY, USA, 1007-1016

Cultural issues



- certain colours are special because they are hard wired

- These colours are often assigned cultural meaning
- E.g. red, white, black

- Red-green, red-blue

Summary: labeling

- Distinctiveness (perceptual distance) vs identification
- Unique hues
  - Don’t choose colours from the same category!
- Contrast with background
  - Luminance
- Compensate for colour deficiency
- Limited number of codes
- Size
  - Objects should not be too small
- Cultural conventions

To Measure

Data to Color

- Types of data values
  - Nominal, ordinal, numeric
  - Qualitative, sequential, diverging
- Types of color scales
  - Hue scale
    - Nominal (labels)
    - Cyclic (learned order)
  - Lightness or saturation scales
    - Ordered scales
    - Lightness best for high frequency
    - More = darker (or more saturated)
    - Most accurate if *quantized*

Quantized
- Signal varies continuously

Discretized
- Restricted to a prescribed set of values

False coloring

- RGB signals are remapped to enhance distinction of features
- Satellite imagery
- 2- channels

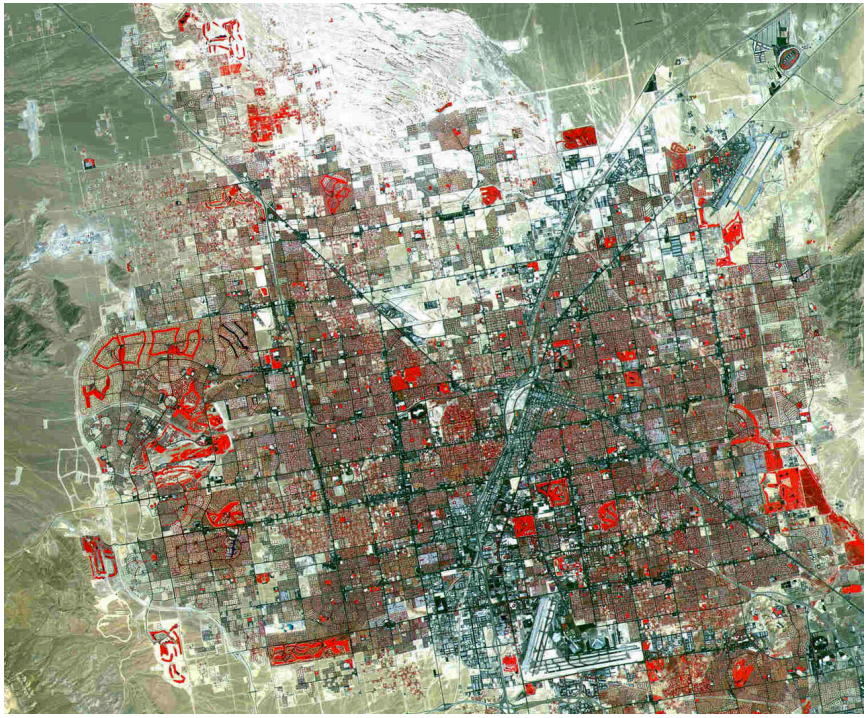


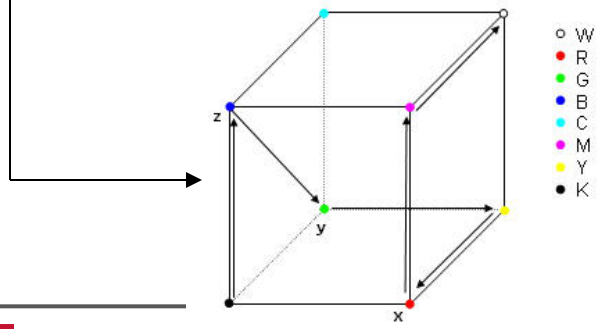
Image courtesy NASA/GSFC/MITI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team

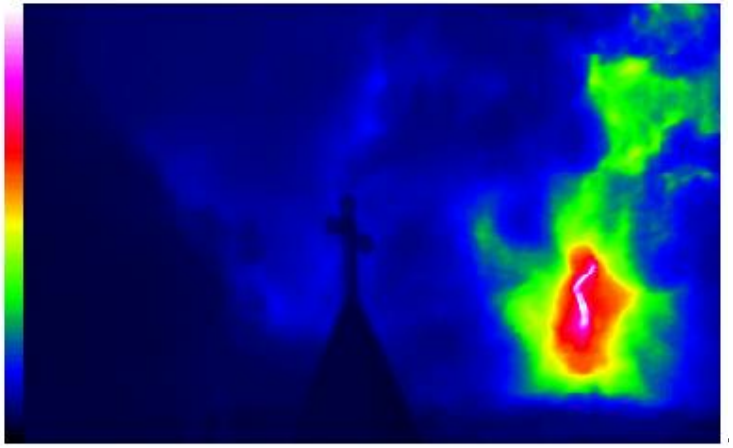
Pseudocoloring

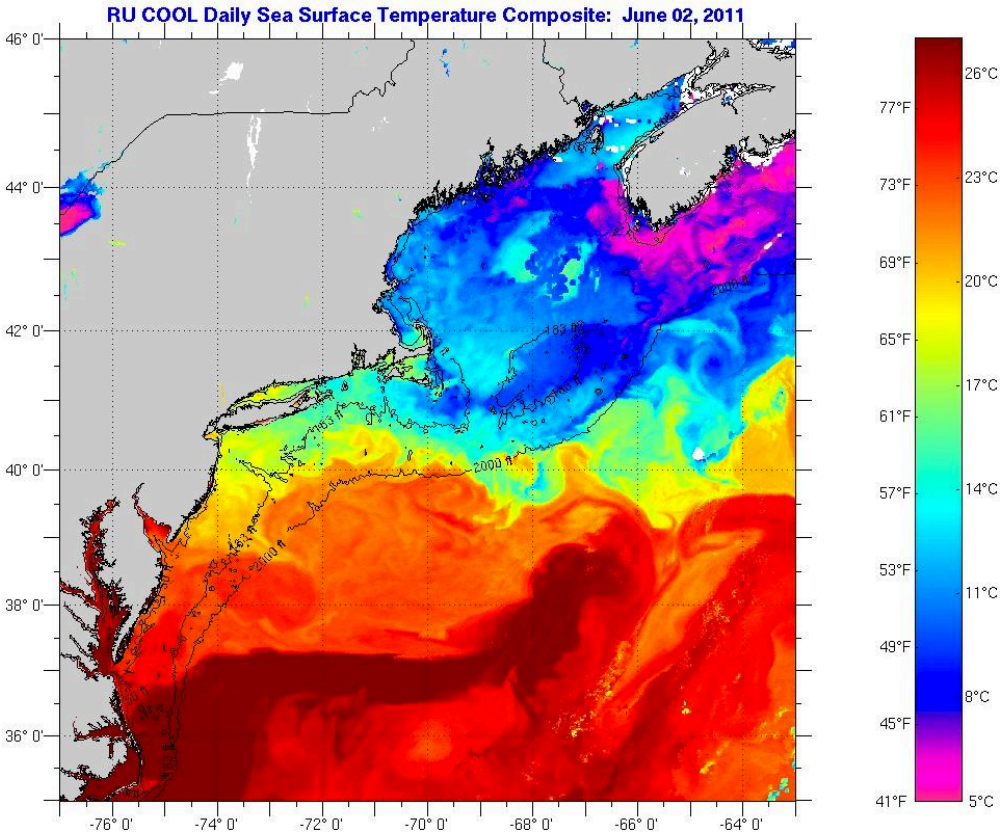
- Pseudocoloring is the technique of representing continuously varying map values with a sequence of colours
- Sometimes overlaid on luminosity information
  - Need to use an **isoluminant** color map to avoid distortion
- “intuitive” based on lightness, saturation
- No perceptually based hue scales
  - Need to be learned

Pseudocoloring

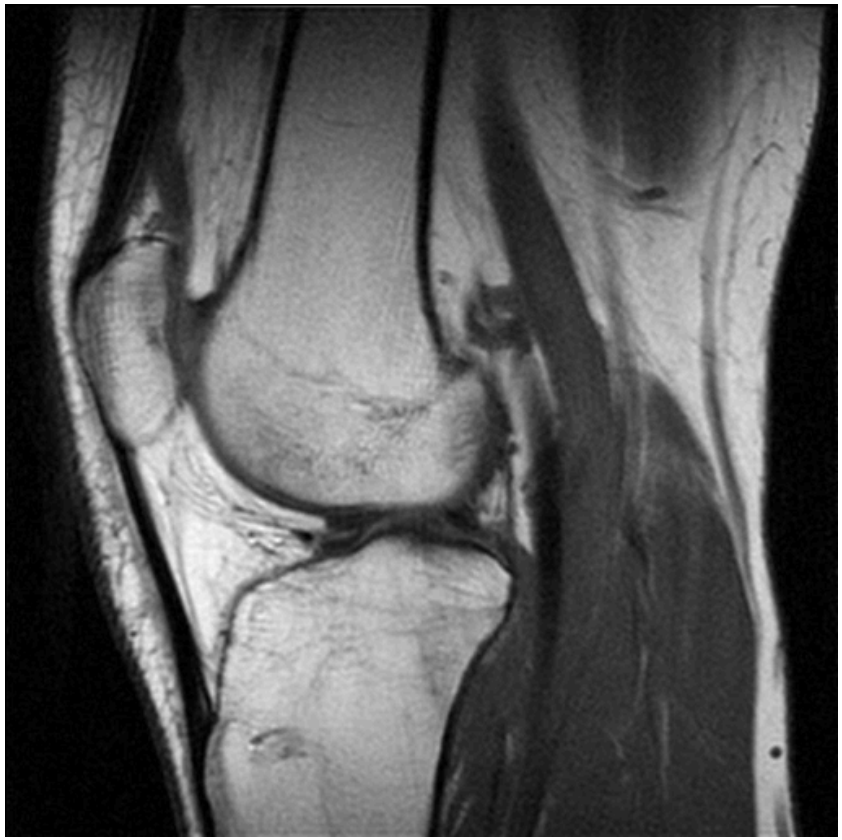
- Derived from a grayscale image
- Maps data channel to colour

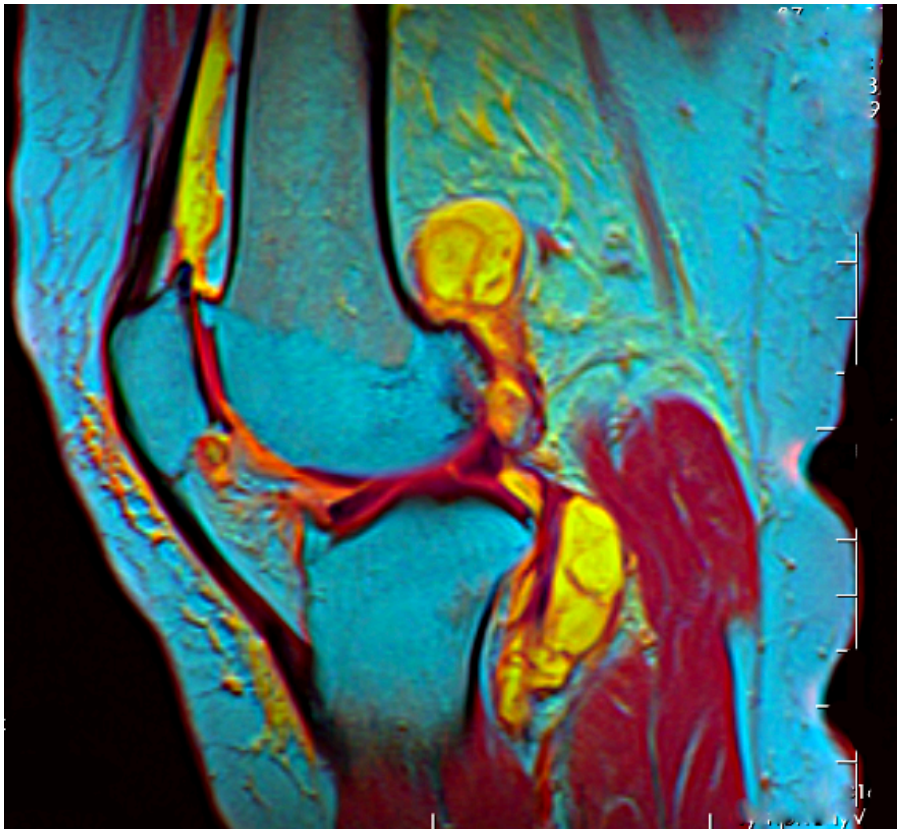




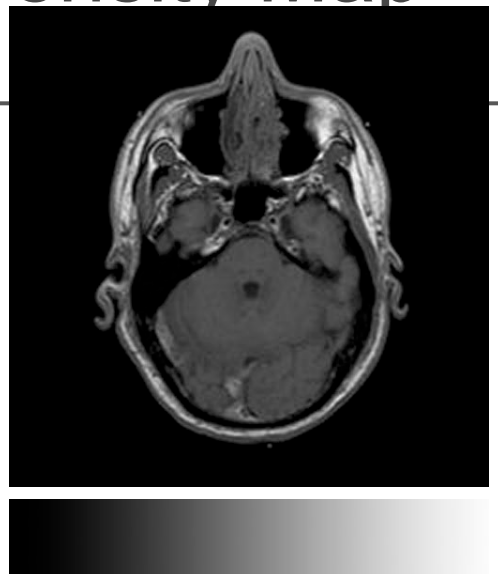

RU COOL Daily Sea Surface Temperature Composite: June 02, 2011
46° 0'
44° 0'
42° 0'
40° 0'
38° 0'
36° 0'
-76° 0'
-74° 0'
-72° 0'
-70° 0'
-68° 0'
-66° 0'
-64° 0'
2000 ft
77°F
73°F
69°F
65°F
61°F
57°F
53°F
49°F
45°F
41°F
26°C
23°C
20°C
17°C
14°C
11°C
8°C
5°C

Frequently used in medicine

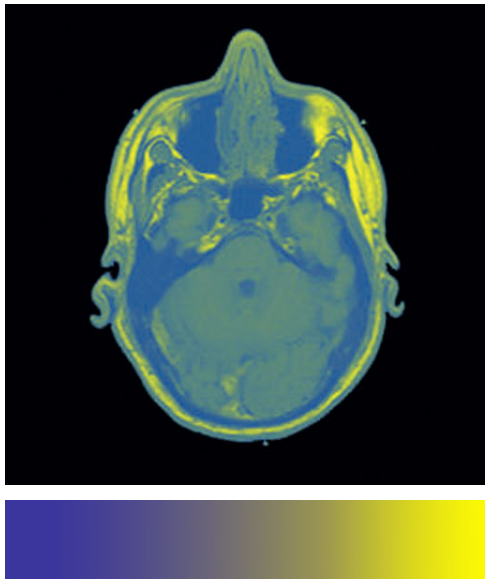




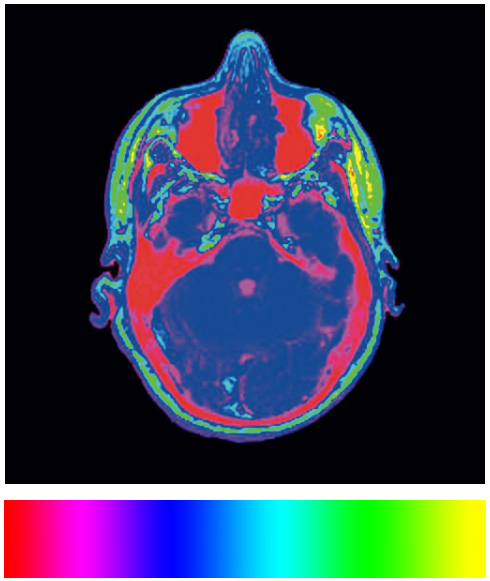
Density Map



Lightness scale

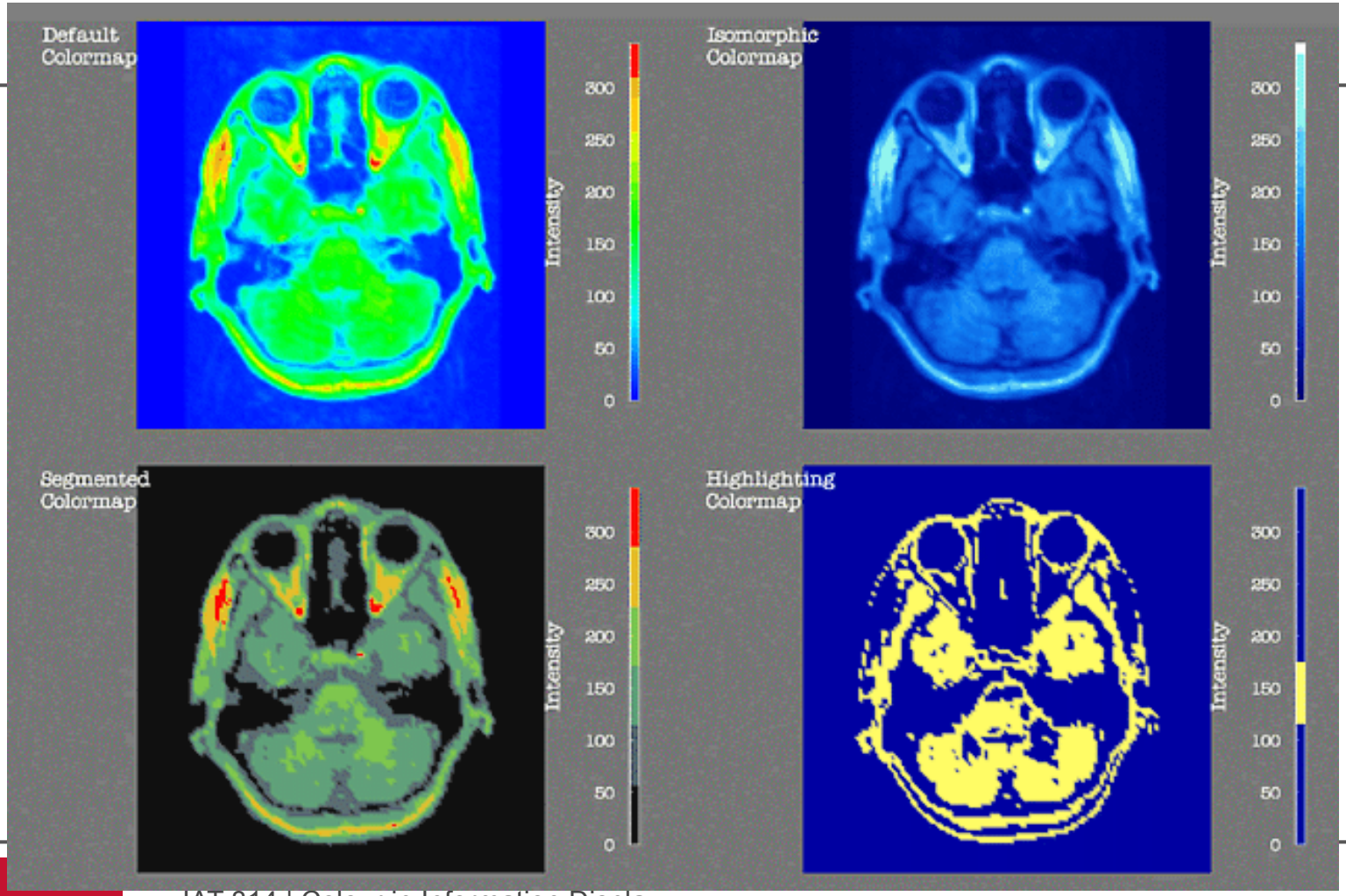


Lightness scale with hue and chroma variation



"Rainbow" hue scale
Unordered hue, lightness

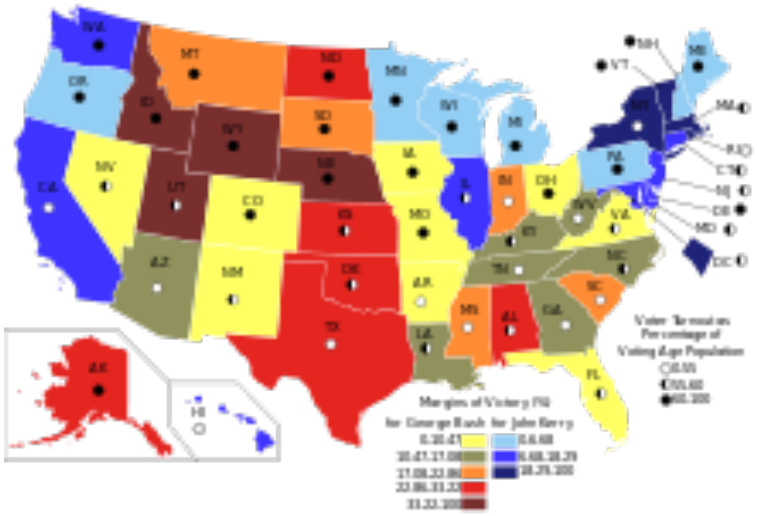
Different Scales



Rogowitz & Treinish, “How not to lie with visualization”

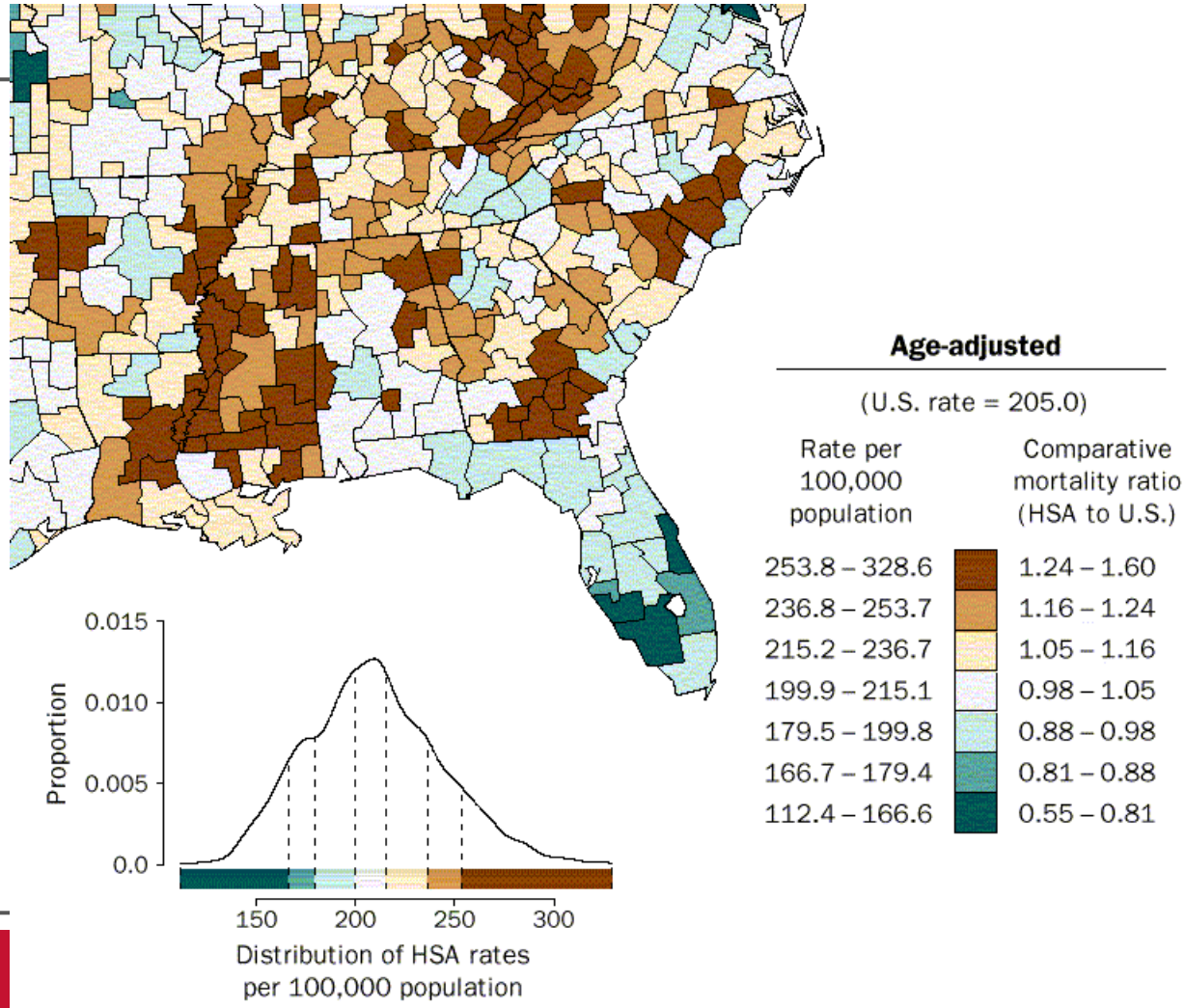
Chloropleth

- areas are colored or patterned proportionally to the category or value of one or more variables being represented
- Discrete
- Typically maps



Thematic Maps

US Census Map

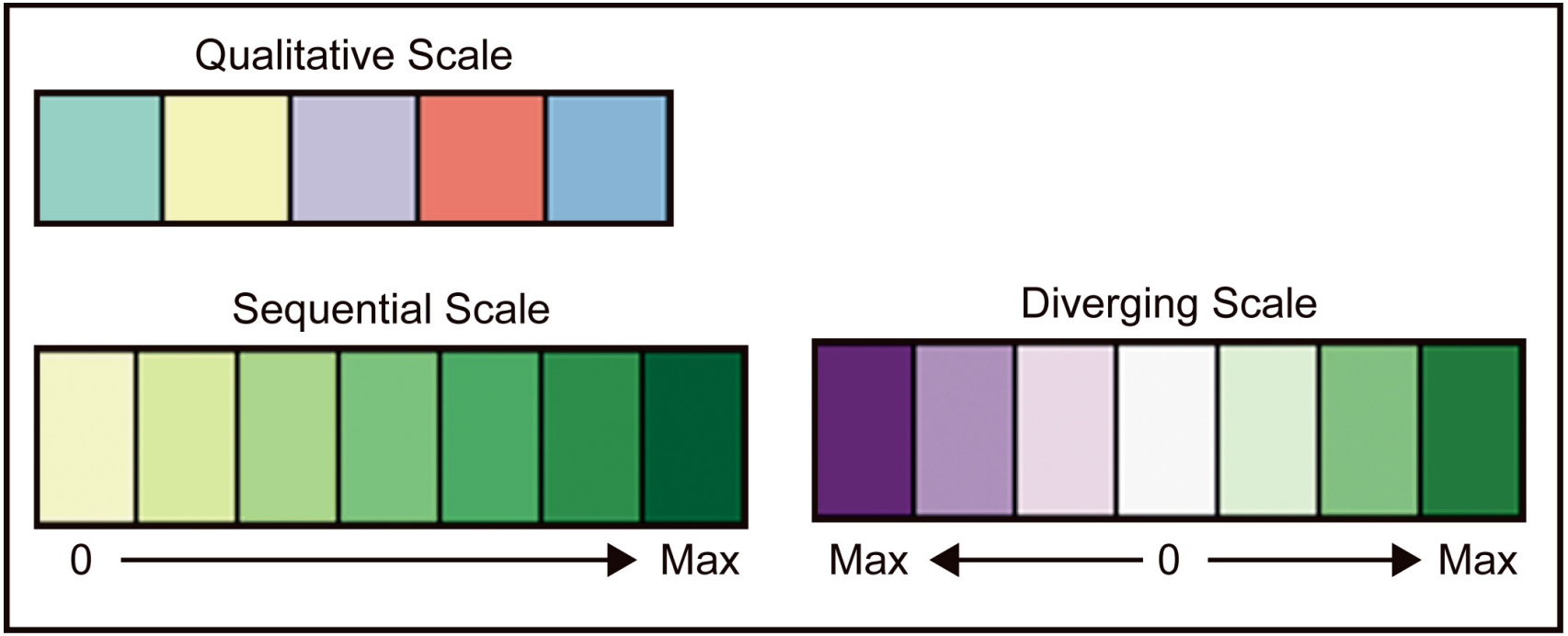


[Mapping Census 2000: The Geography of U.S. Diversity]

Brewer Scales

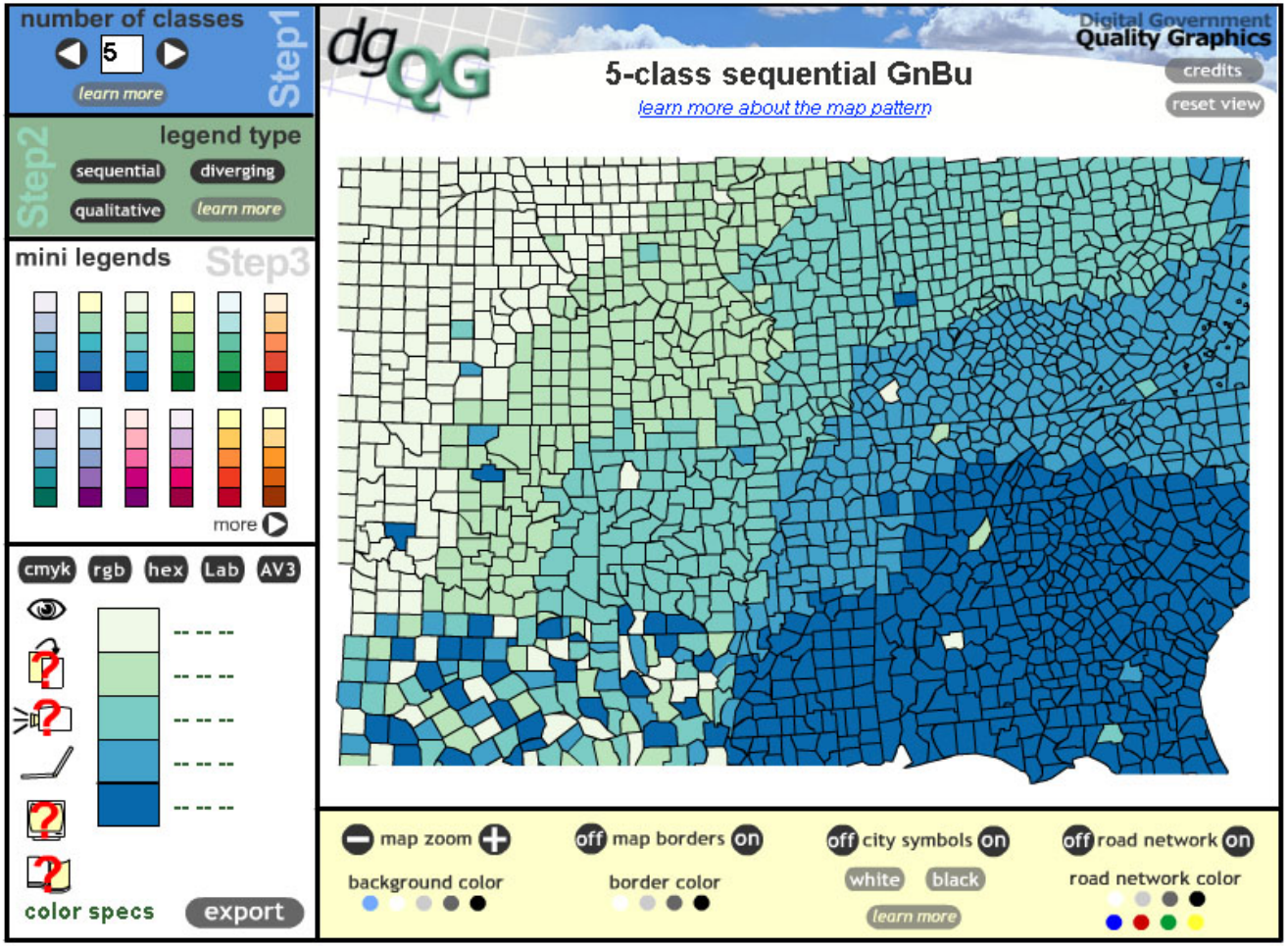
- Qulitative scales
  - nominal
  - Distinct hues, but similar emphasis
- Sequential scale
  - Vary in lightness and saturation
  - Vary slightly in hue
- Diverging scale
  - Complementary sequential scales
  - Neutral at “zero”
  - Cross-fade through a neutral color

Brewer's Categories



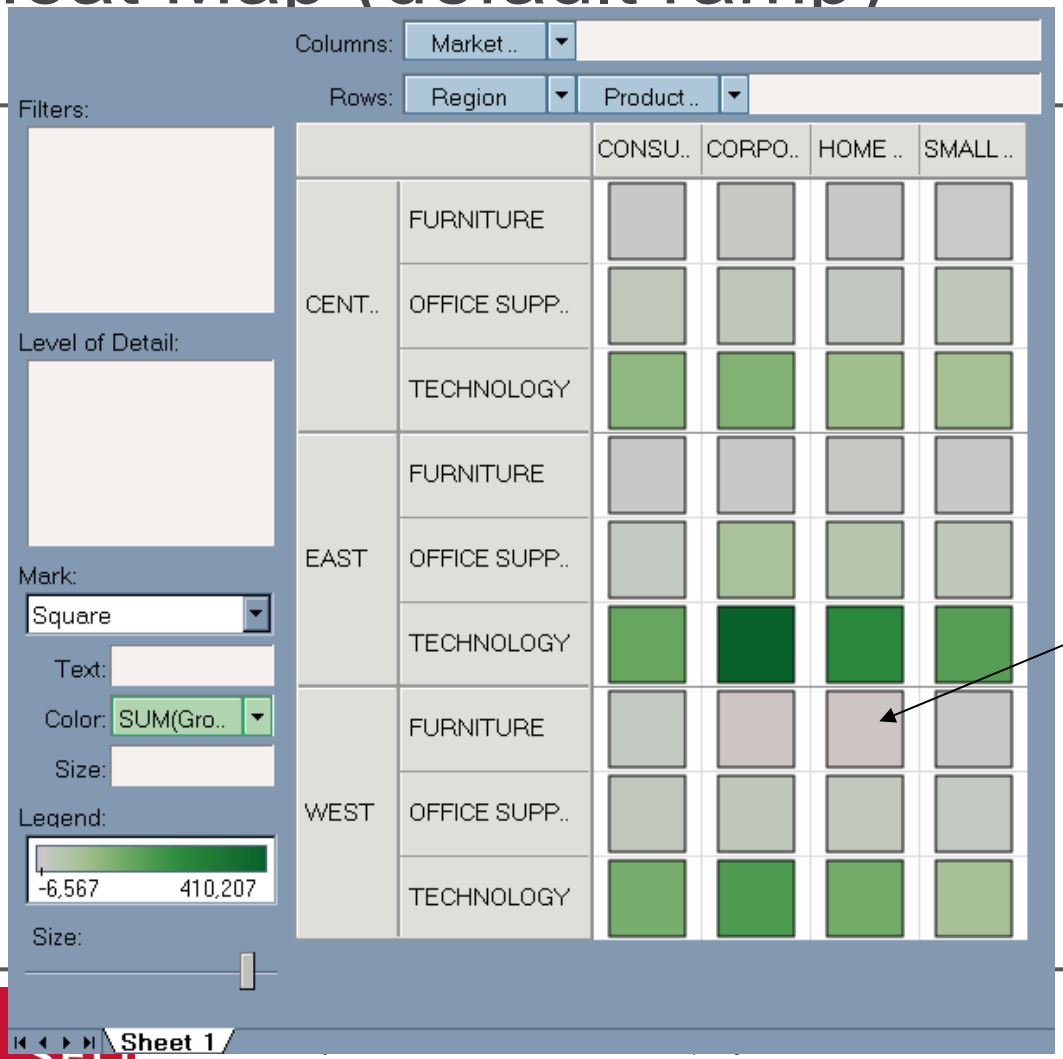
Color Brewer

www.colorbrewer.org



This material is based upon work supported by the National Science Foundation under Grant No. 9983451, 9983459, 9983461

Heat Map (default ramp)

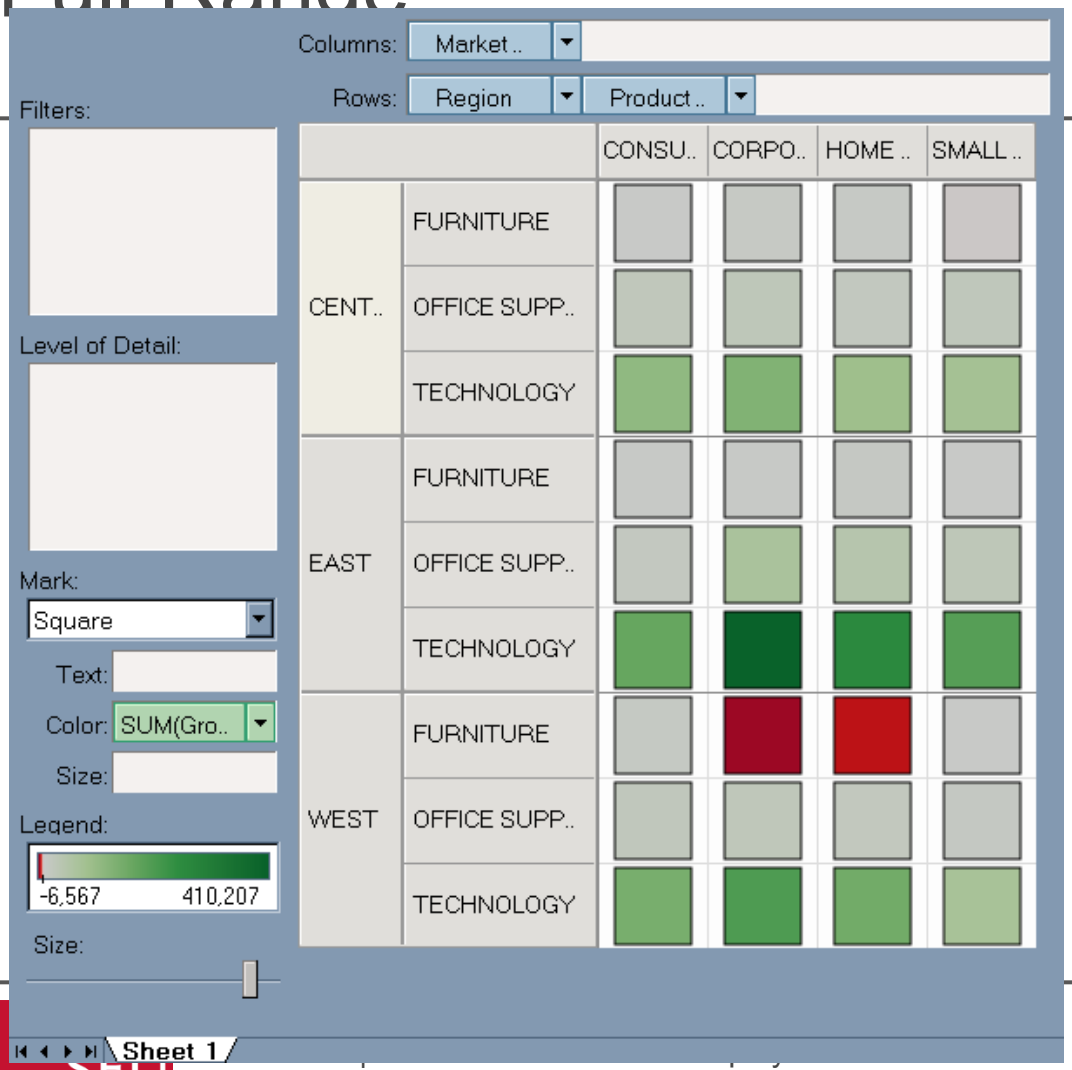


Skewed Data

Slightly negative

www.tableausoftware.com

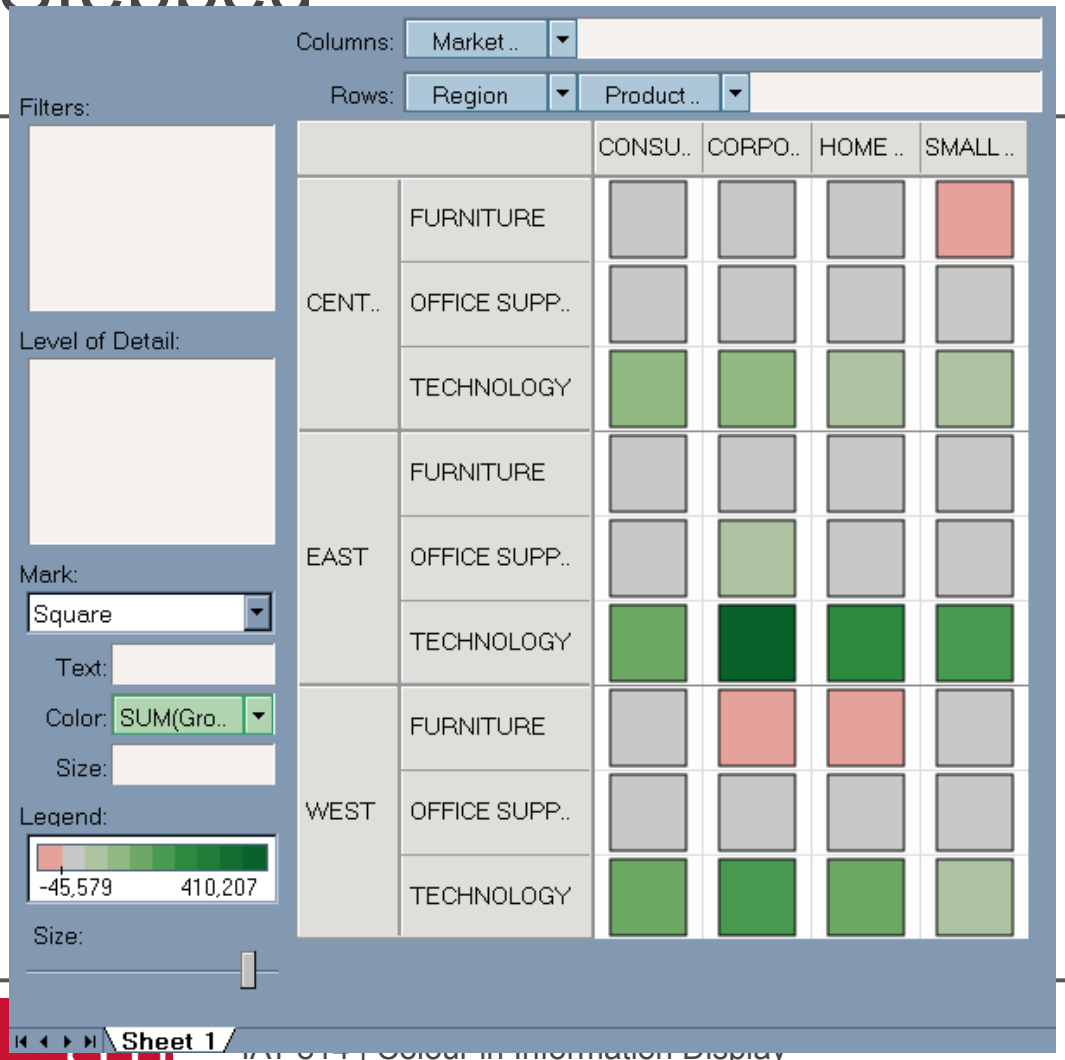
Full Range



Skewed Data

www.tableausoftware.com

Stepped

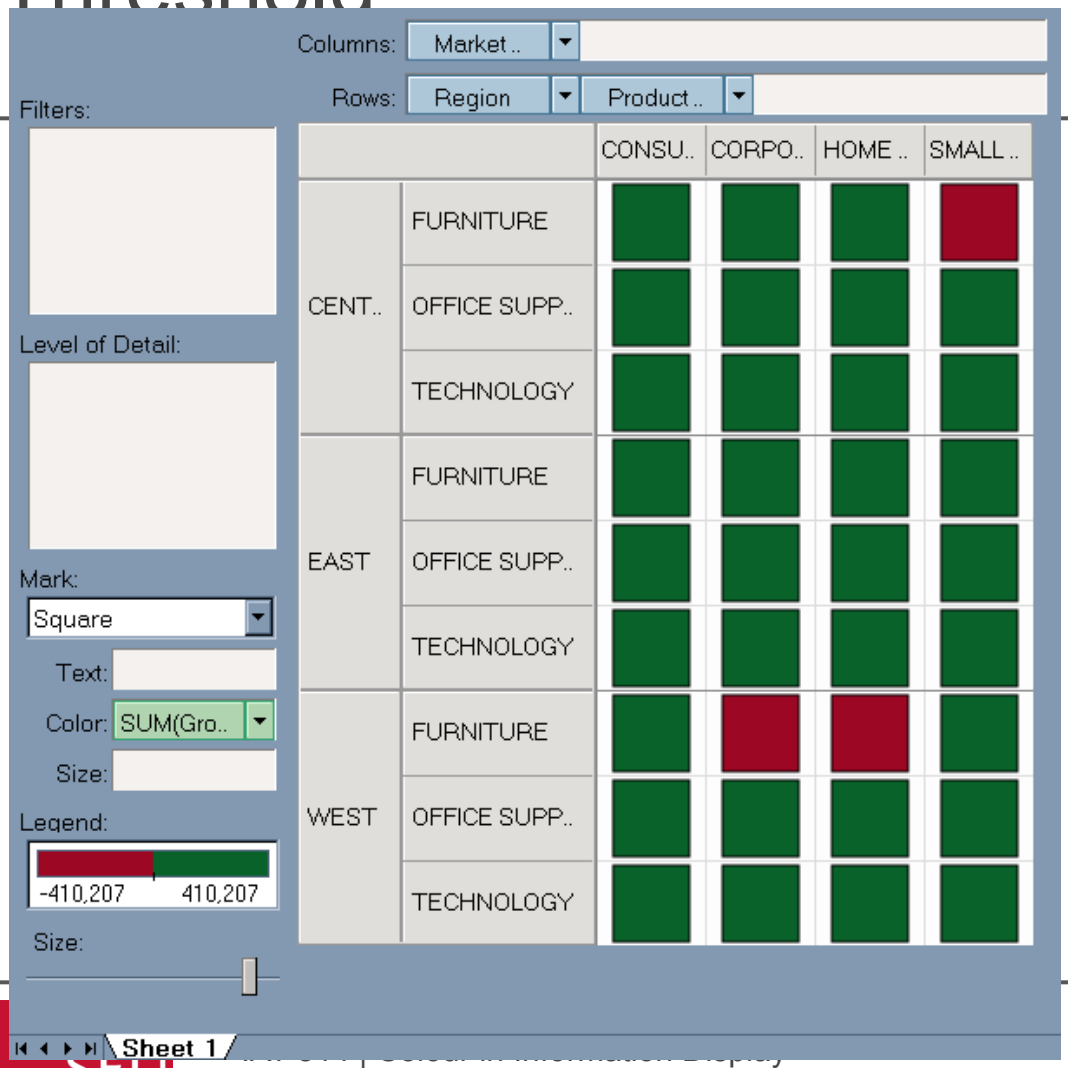


Skewed Data

www.tableausoftware.com

Threshold

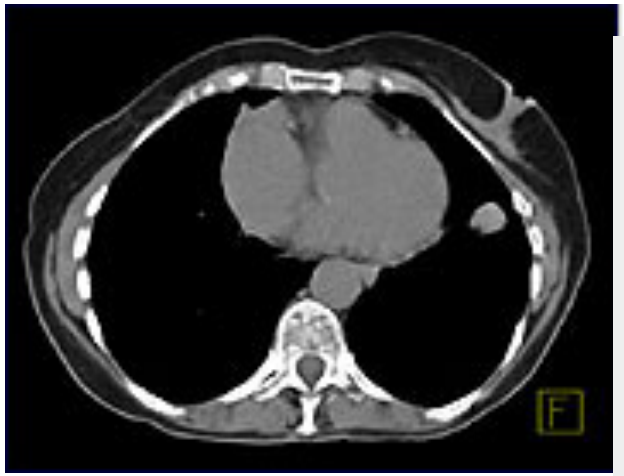
Skewed Data



www.tableausoftware.com

Color and Shading

- Shape is defined by lightness (shading)
- “Color” (hue, saturation) labels



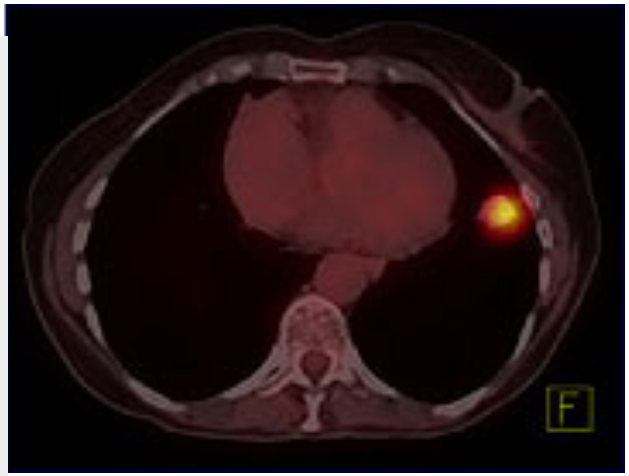


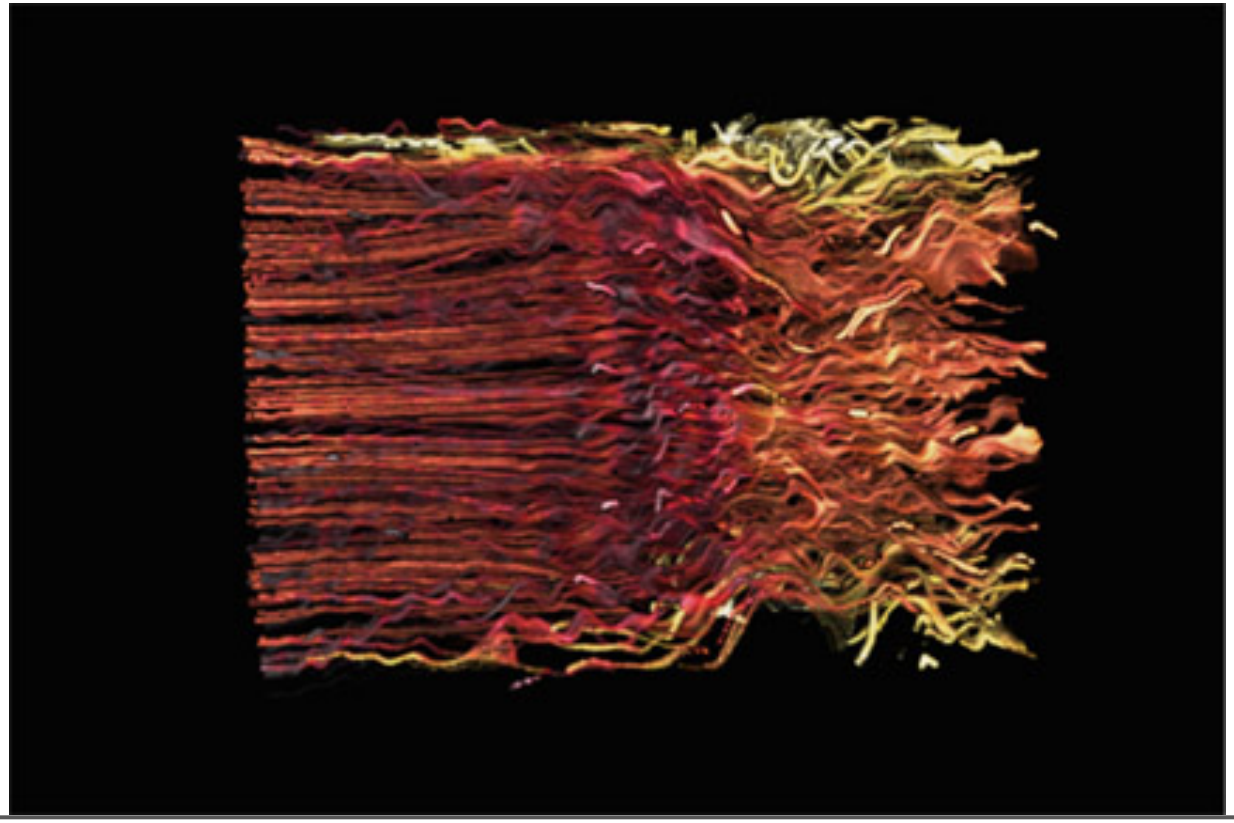
Image co y of Siemens

CT image (defines shape)

PET color highlights tumor

Color Overlay (Temperature)

- 3D line integral convolution to visualize 3D flow (LIC).
- Color varies from red to yellow with increasing temperature



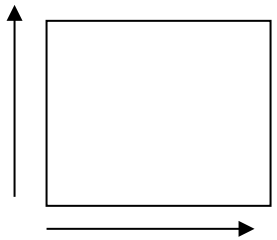
Victoria Interrante and Chester Grosch, U. Minnesota

http://www-users.cs.umn.edu/~interran/3Dflow.html

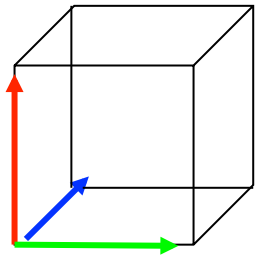
Multivariate Color Sequences

How many dimensions?

- Univariate scale is a path in a colour space
  - Progression along a line



- Multivariate is:
  - Plane? 2D
  - Volume ? 3D
  - Rules for color mixing
- Only perceptual coding is 2D
  - lightness x saturation
- Color for multivariate only works well for highly quantized data
  - Like a mnemonic for a labeling scheme
-



Multi-dimensional Scatter plot

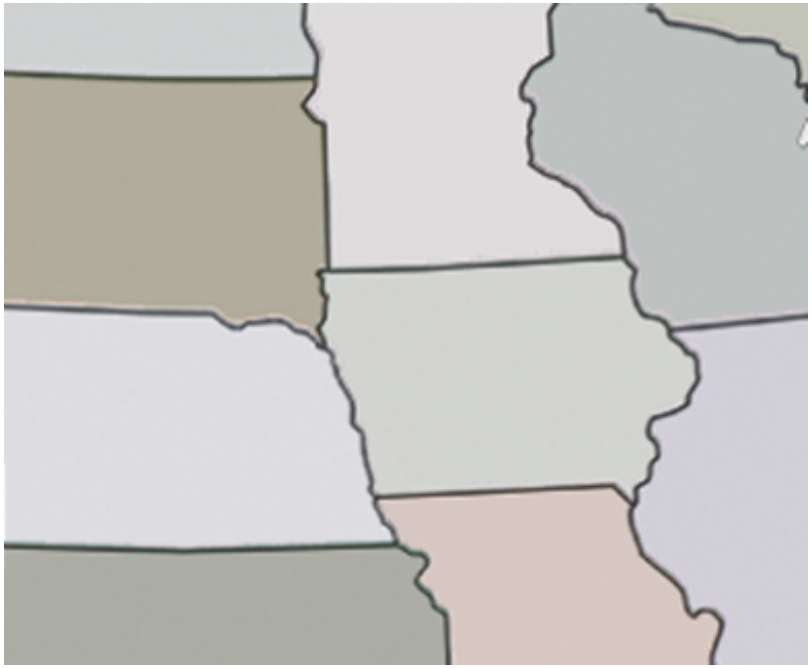
Variable 1, 2 → X, Y
Variable 3, 4, 5 → R, G, B

Do people interpret color blends as sums of variables?

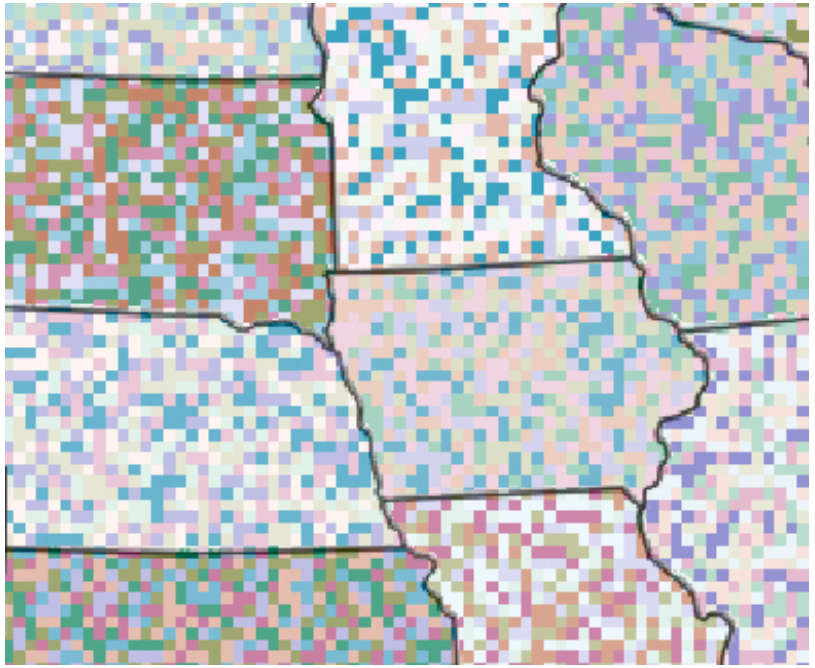
Using Color Dimensions to Display Data Dimensions Beatty and Ware

Color Weaves

6 variables = 6 hues, which vary in brightness



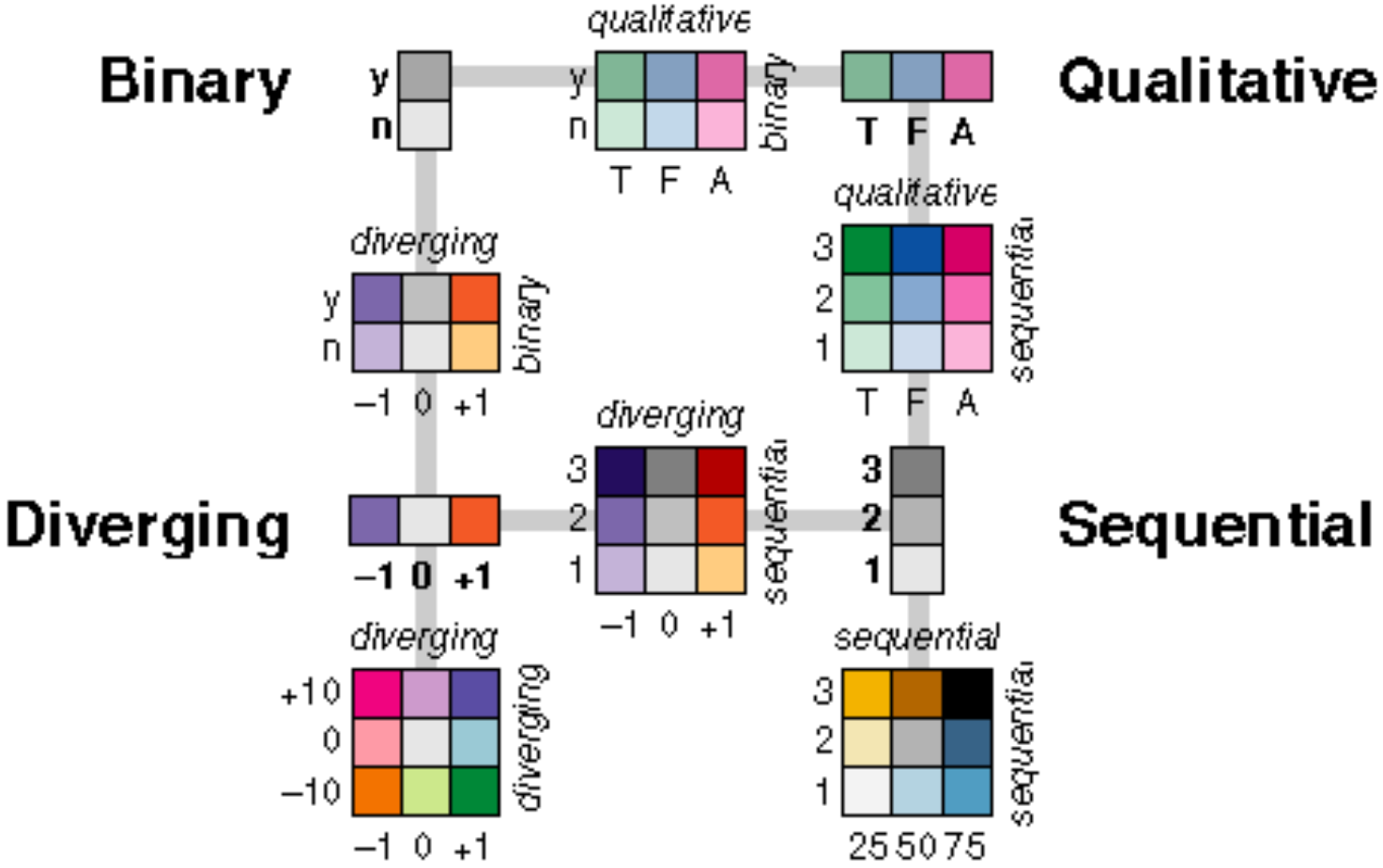
Additive mixture (blend)



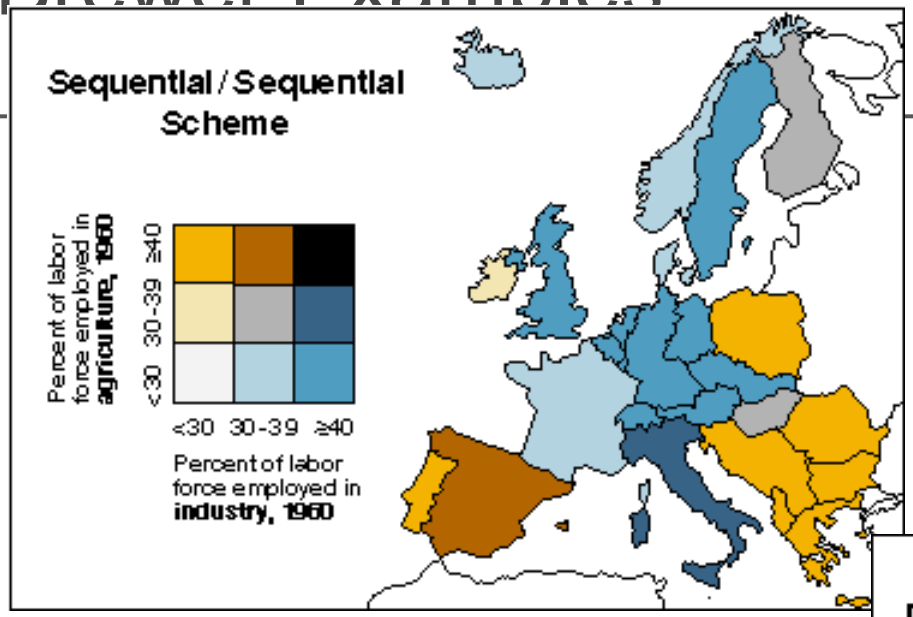
Spatial texture (weave)

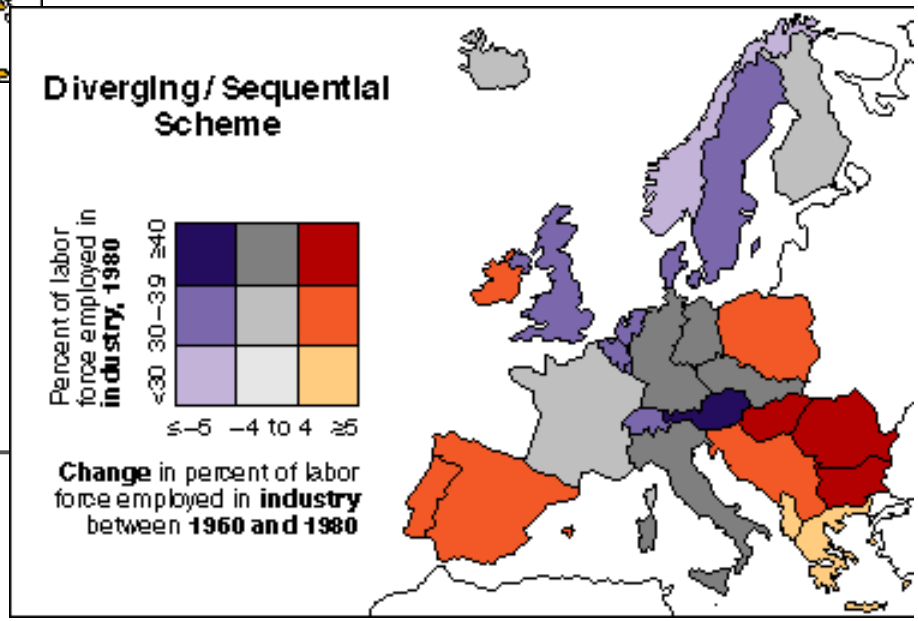
Weaving versus Blending (APGV06 and SIGGRAPH poster)
Haleh Hagh-Shenas, Victoria Interrante, Christopher Healey and Sunghee Kim

Brewer System



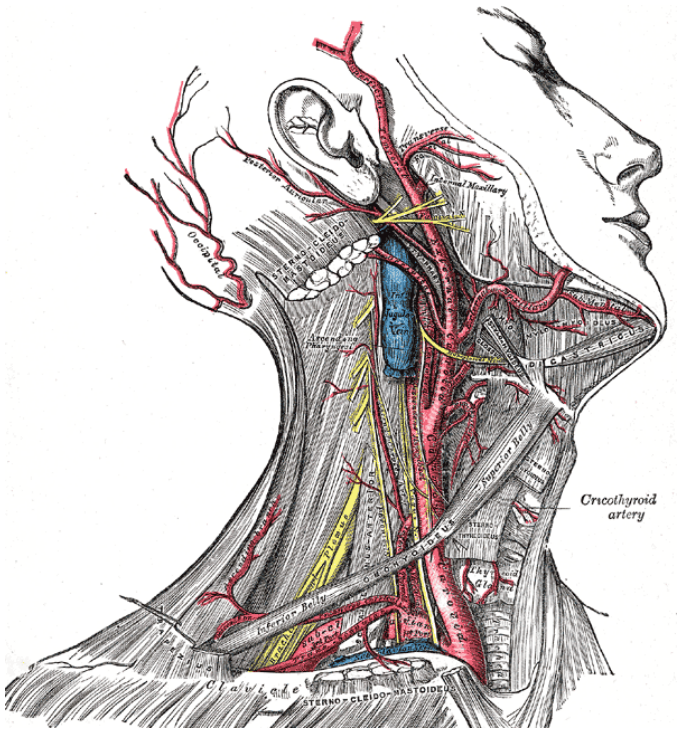
Brewer Examples





Illustrative Color: To Represent or Imitate Reality

Gray's *Anatomy of the Human Body*

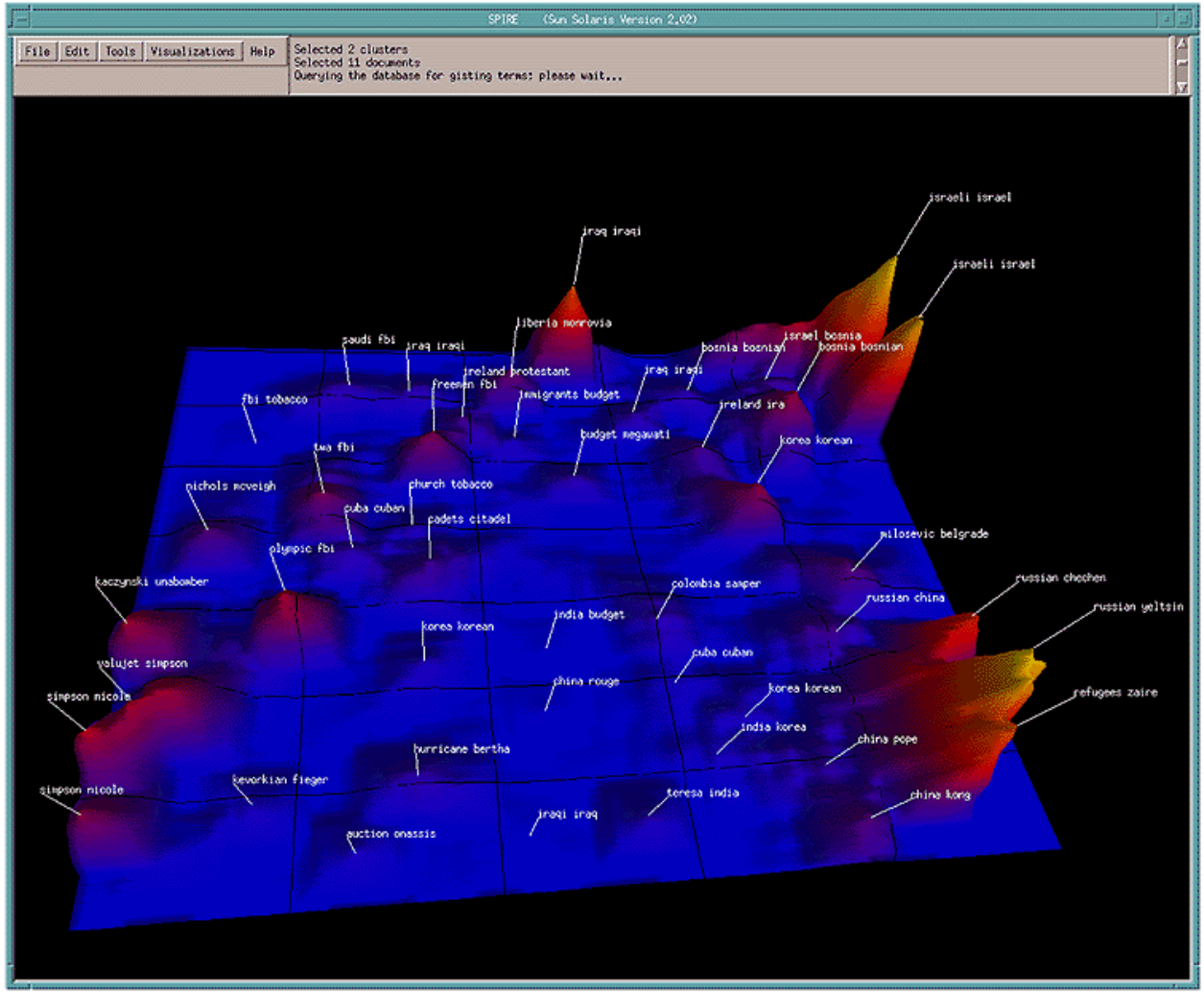


www.bartleby.com/107/illus520.html

Map of Point Reyes

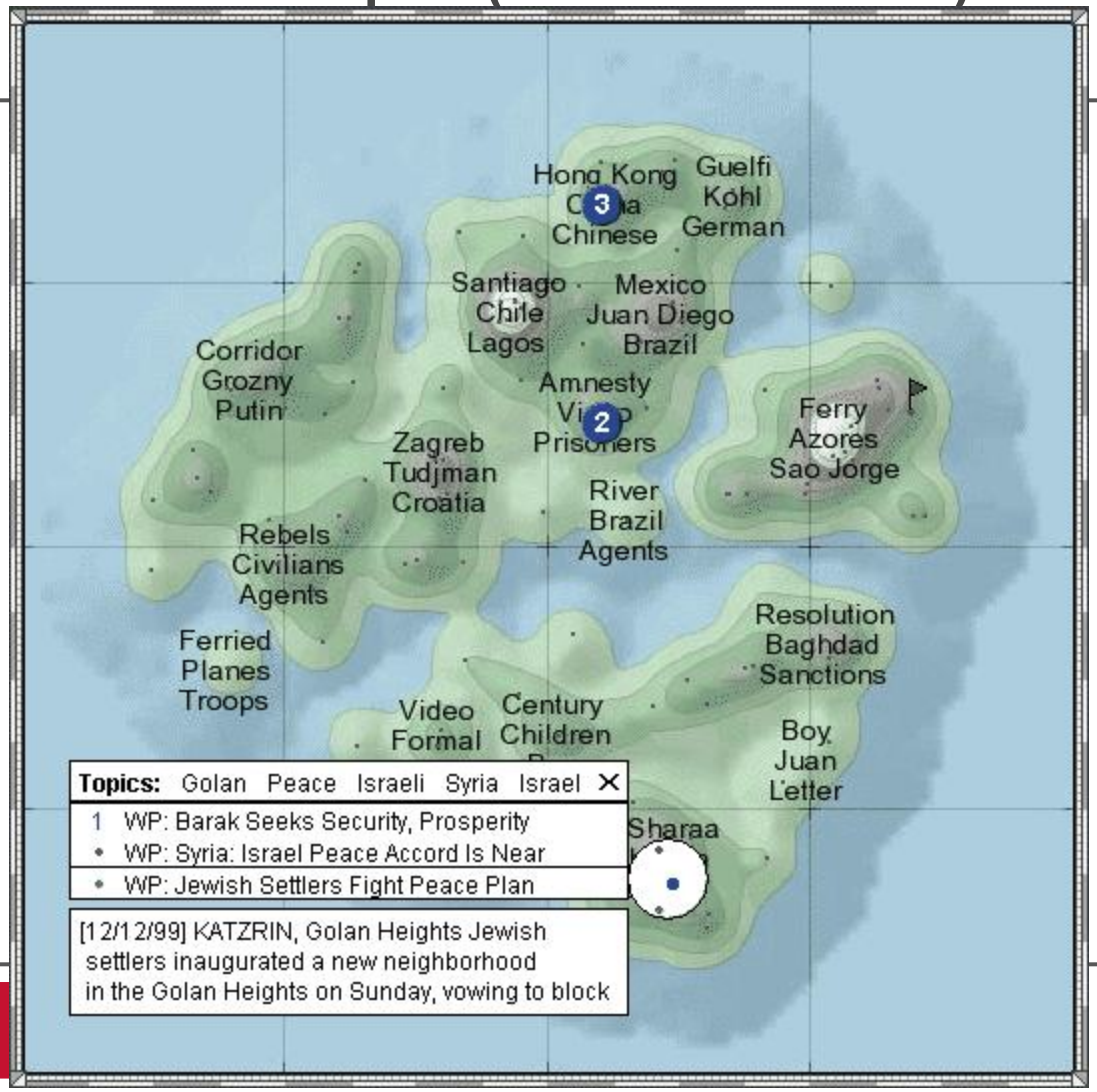
www.nps.gov

ThemeView (original)

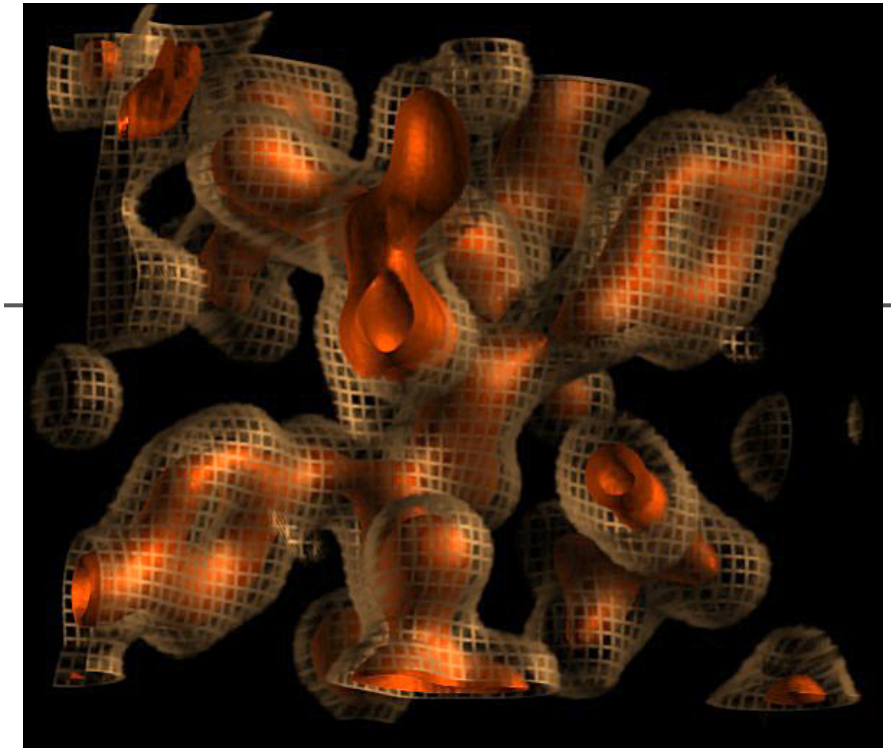


Courtesy of Pacific Northwest National Laboratories

ThemeScape (commercial)

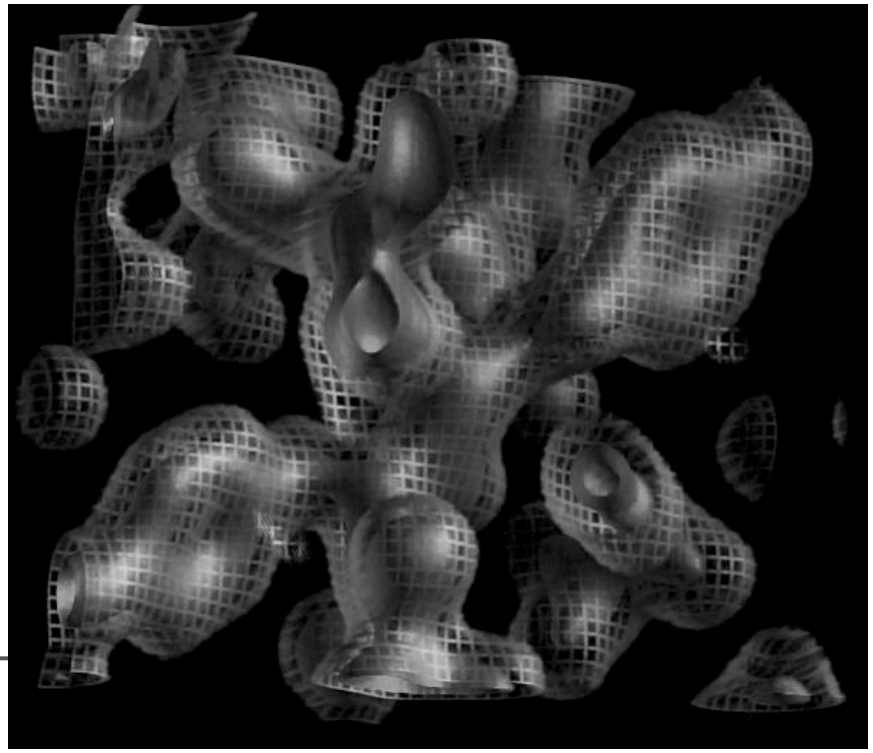


Courtesy of Cartia



Which has more information?

Which would you rather look at?



Visualization of isoelectron density surfaces around molecules

Marc Levoy (1988)

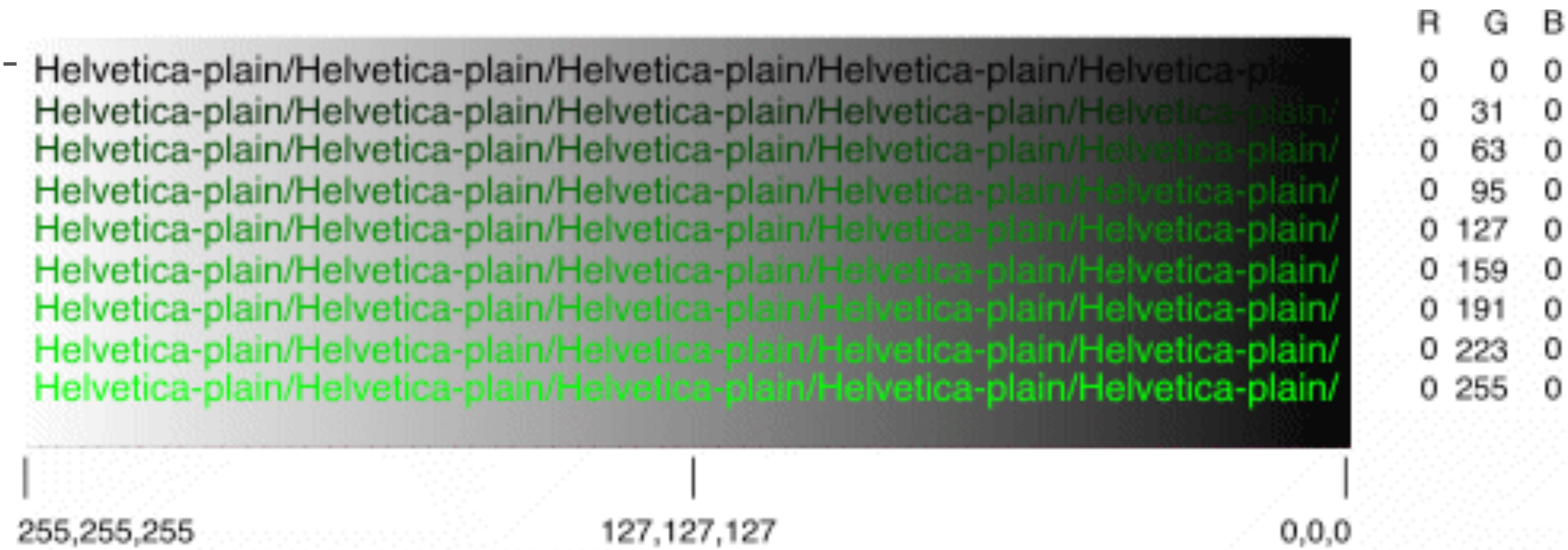
More Tufte Principles

- Limit the use of bright colors
  - Small bright areas, dull backgrounds
- Use the colors found in nature
  - Familiar, naturally harmonious
- Use grayed colors for backgrounds
  - Quiet, versatile
- Create color unity
  - Repeat, mingle, interweave

Controlling value: Get it right in black & white !

- Value
  - Perceived lightness/darkness
  - Controlling value primary rule for design
- Value defines shape
  - No edge without lightness difference
  - No shading without lightness variation
- Value difference (contrast)
  - Defines legibility
  - Controls attention
  - Creates layering

Controls Legibility



colorusage.arc.nasa.gov

Legibility

Drop Shadows

Drop Shadow

Drop shadow adds edge

Primary colors on white

Primary colors on white

Primary colors on white

Primary colors on white

Primary colors on white

Primary colors on white

Primary colors on black

Primary colors on black

Primary colors on black

Primary colors on black

Primary colors on black

Primary colors on black

Readability

If you can't use color wisely,
it is best to avoid it entirely
Above all, do no harm

If you can't use color wisely,
it is best to avoid it entirely
Above all, do no harm.

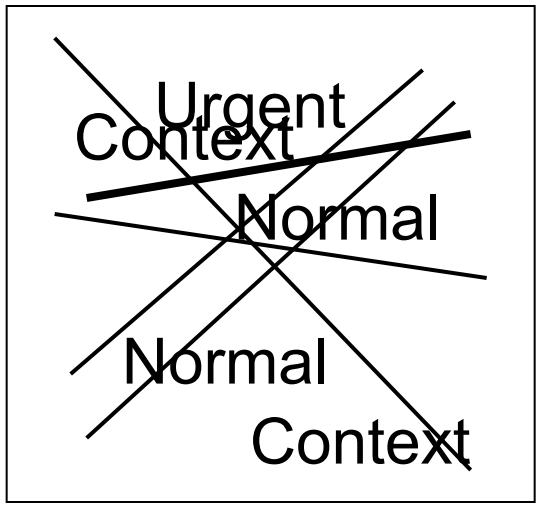
Why does the logo work?

Why does this logo work so well?

Value control

Contrast and Layering

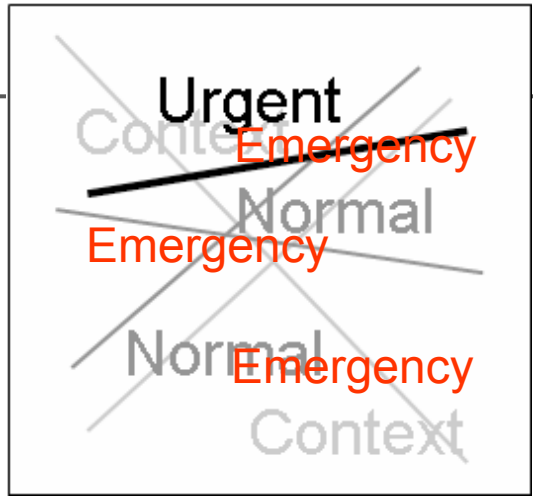
- Value contrast creates layering

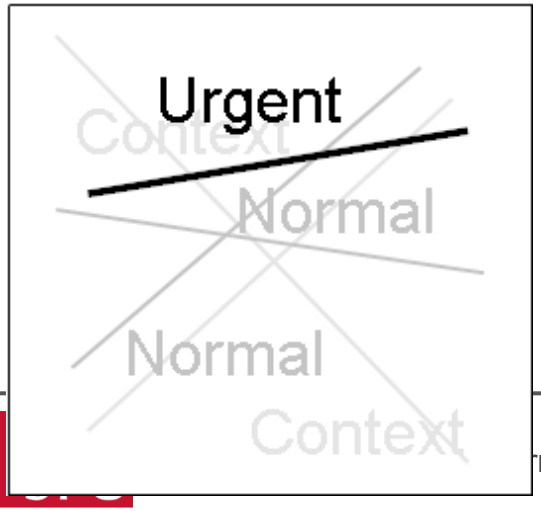


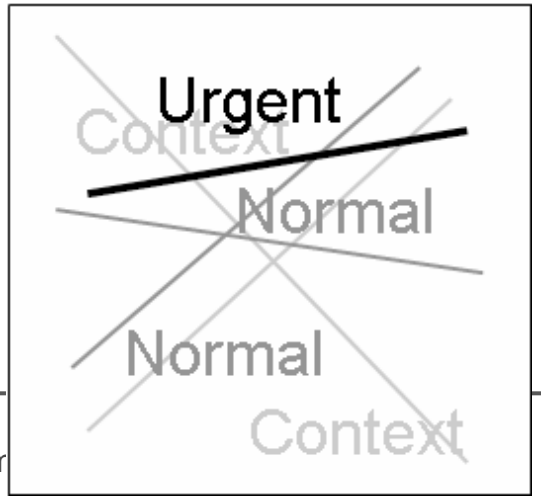
colorusage.arc.nasa.gov

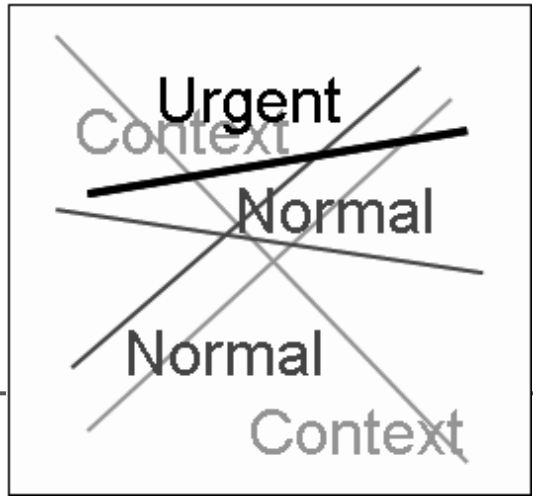
What Defines Layering?

- Perceptual features
  - Contrast (especially lightness)
  - Color, shape and texture
- Task and attention
  - Attention affects perception
- Display characteristics
  - Brightness, contrast, “gamma”









General guidelines … or from Tufte to practice [Stone, Ware]

- Assign colour according to function
- Use **contrast** to highlight
- Use analogy to group
- Control value contrast for legibility
- Break isoluminance with borders

From principles to palettes

- Limit palette to 2 or 3 them
- Different choices cor

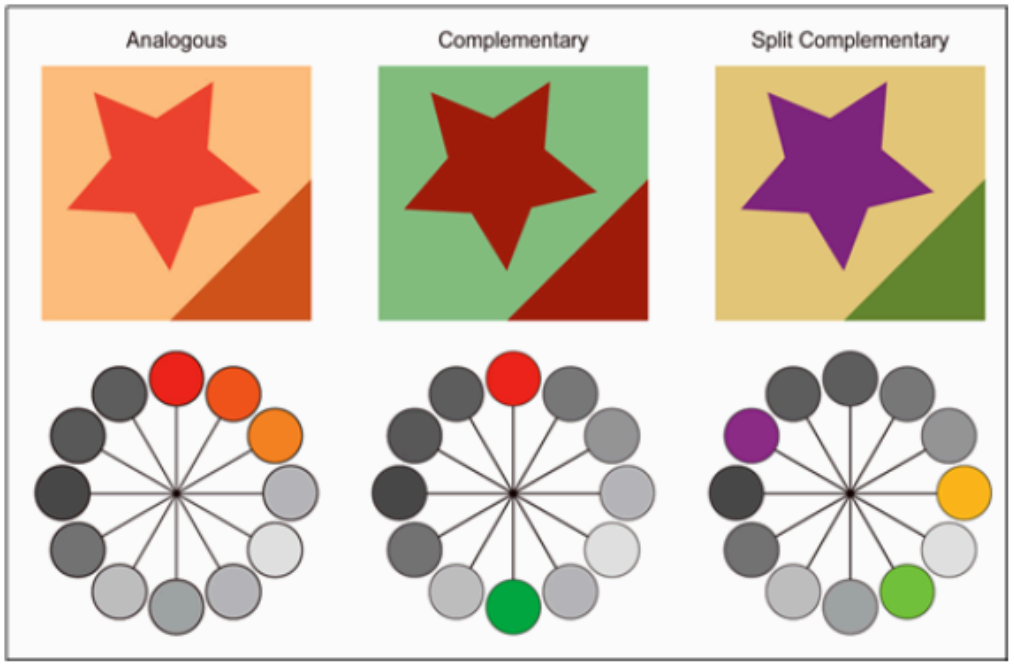
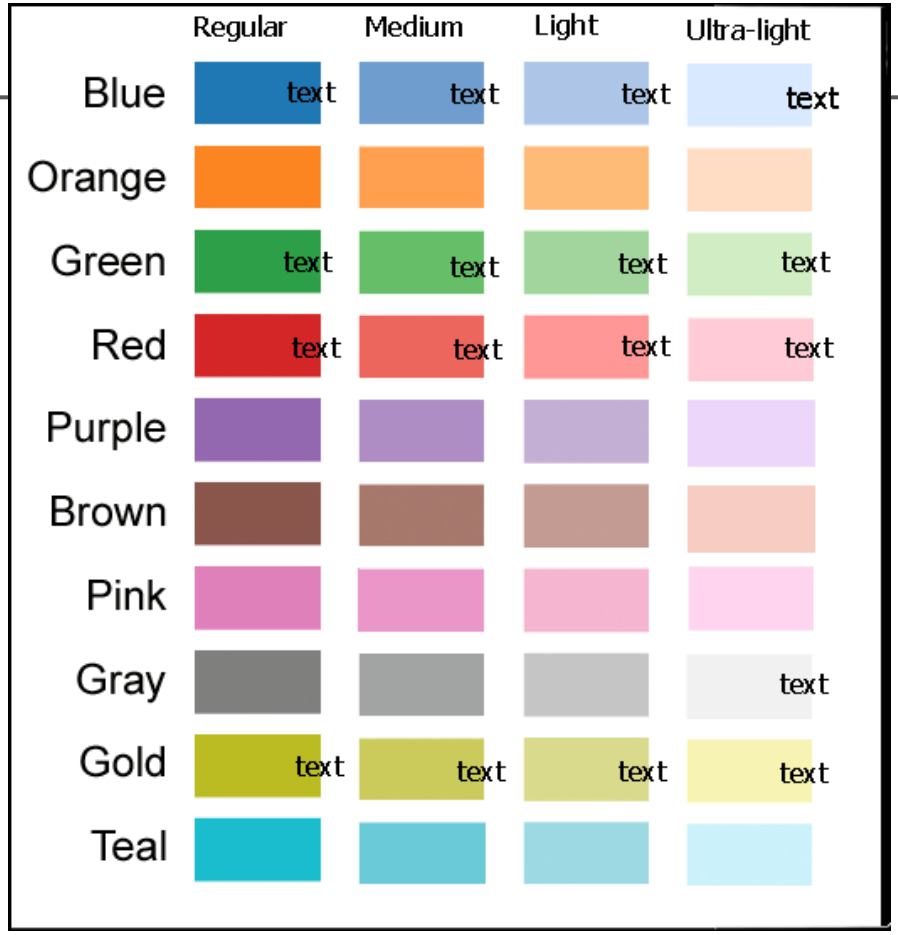


Tableau Color Example

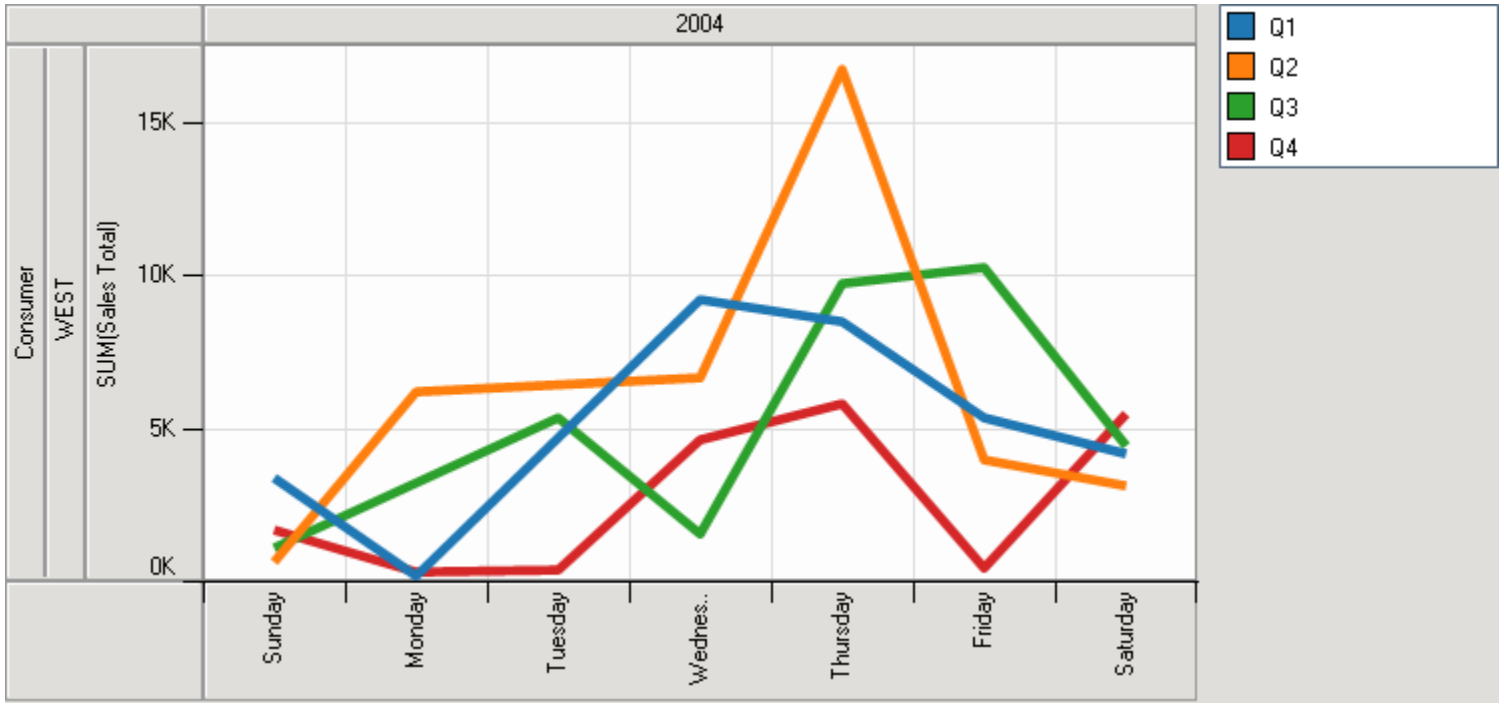
- Color palettes
  - How many? Algorithmic?
  - Basic colors (regular and pastel)
  - Extensible? Customizable?
- Color appearance
  - As a function of size
  - As a function of background
- Robust and reliable color names

Tableau™ Colors

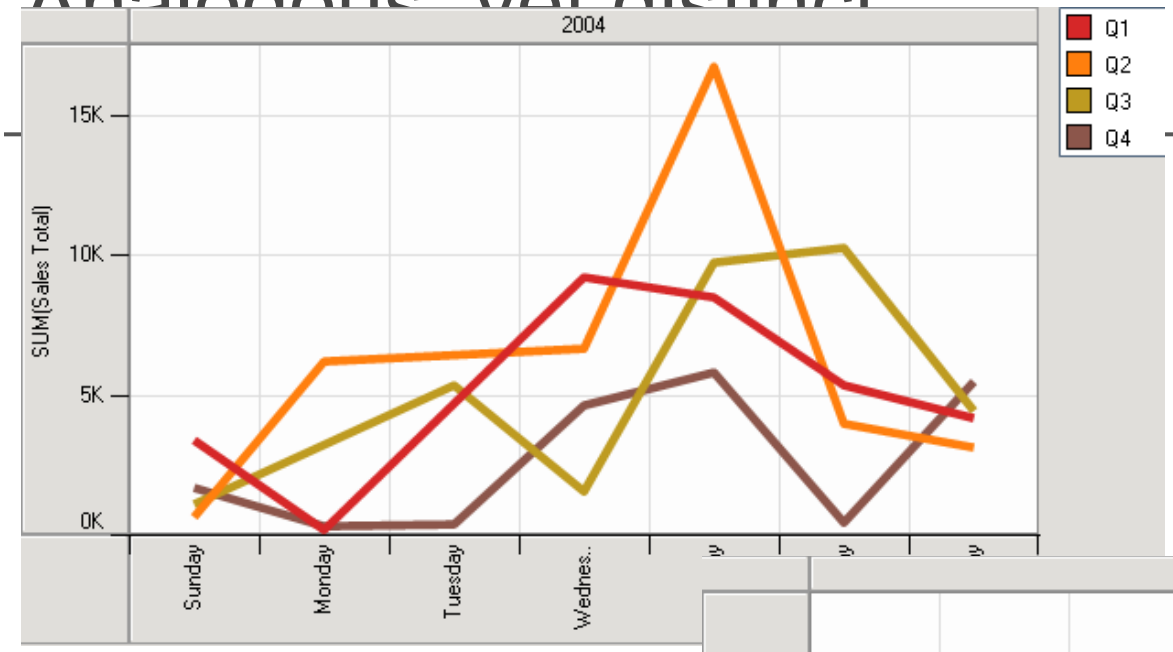


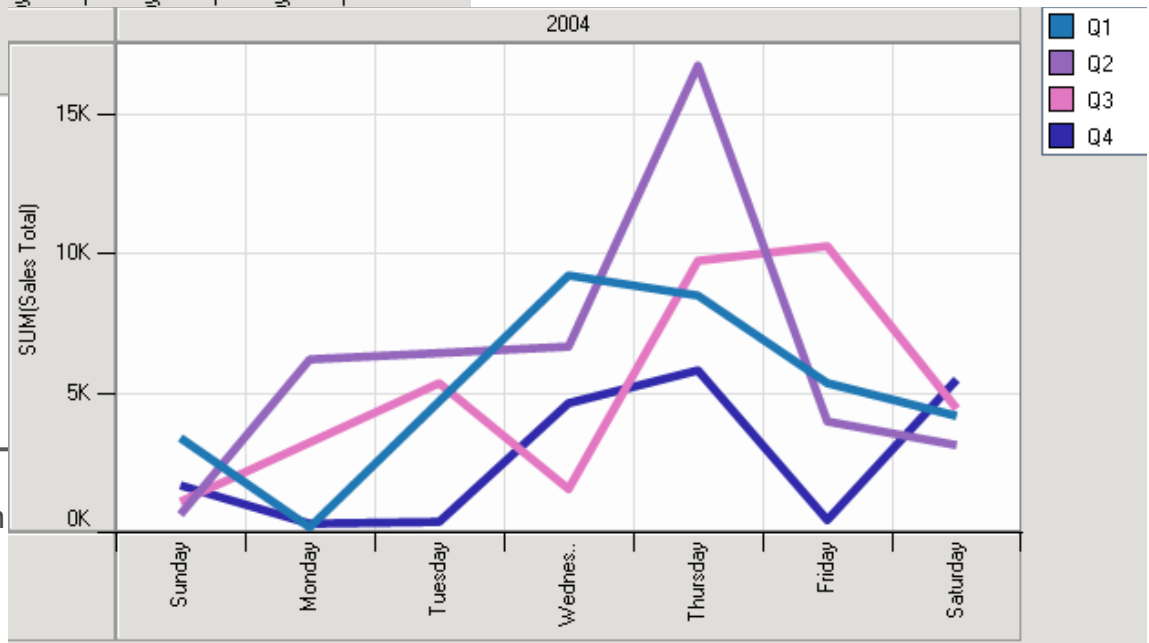
www.tableausoftware.com

Maximum hue separation

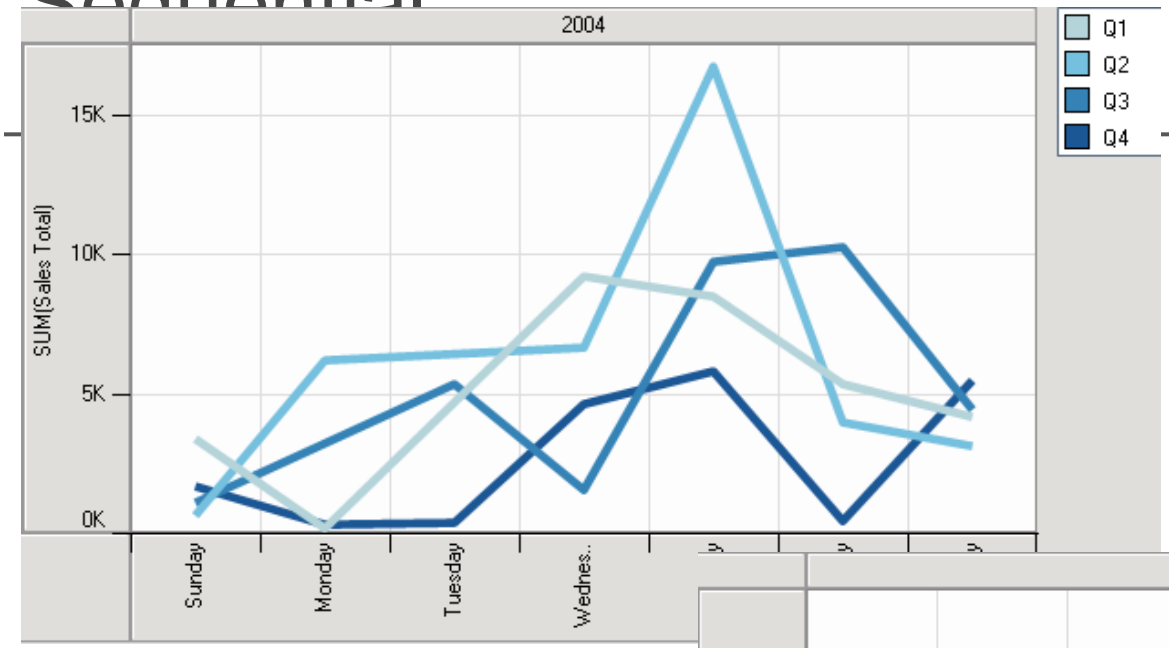


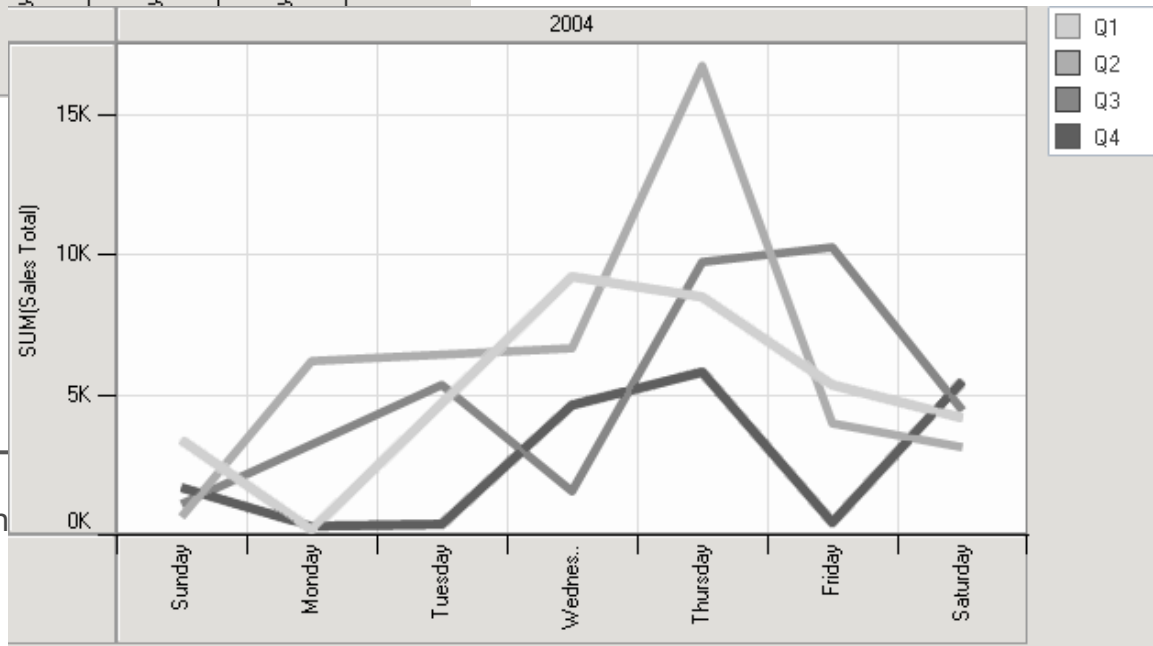
Analogous, yet distinct





Sequential


2004
Q1
Q2
Q3
Q4
15K
10K
5K
0K
SUM(Sales Total)
Sunday
Monday
Tuesday
Wednes..


2004
Q1
Q2
Q3
Q4
15K
10K
5K
0K
SUM(Sales Total)
Sunday
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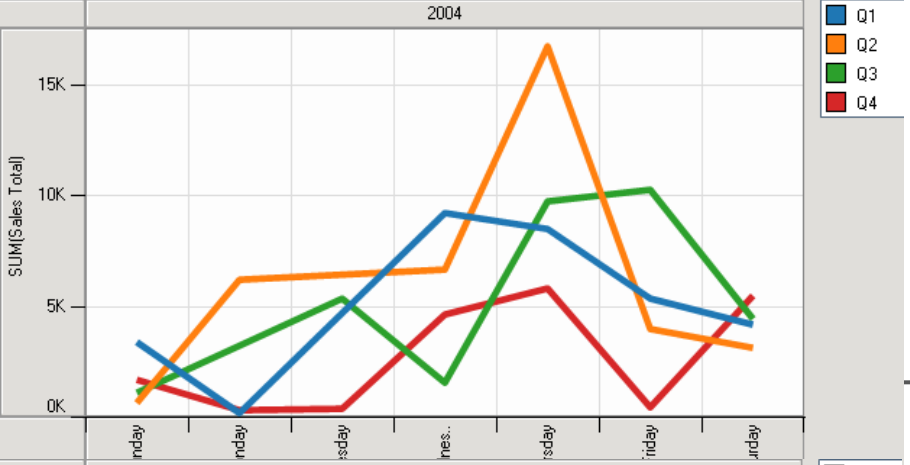
Wednes..
Thursday
Friday
Saturday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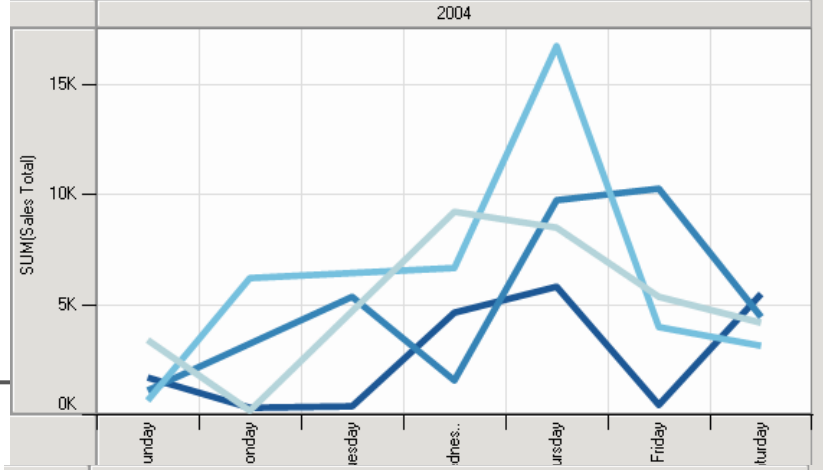
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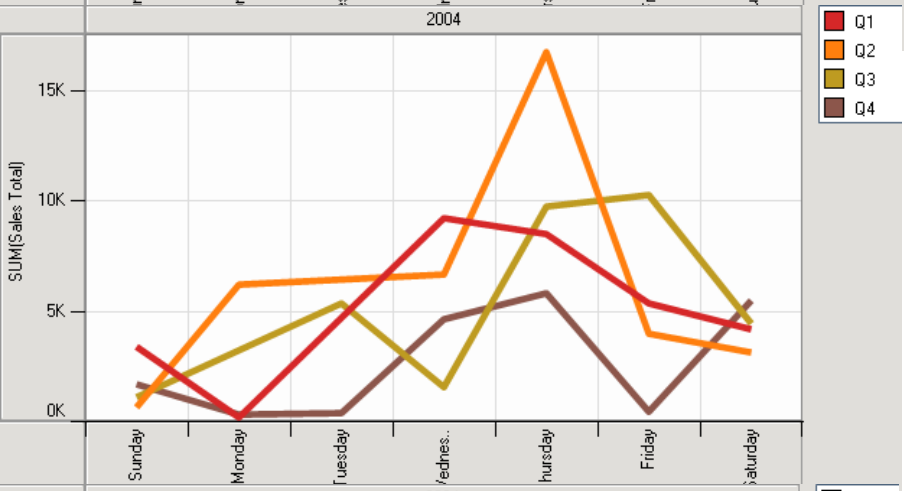
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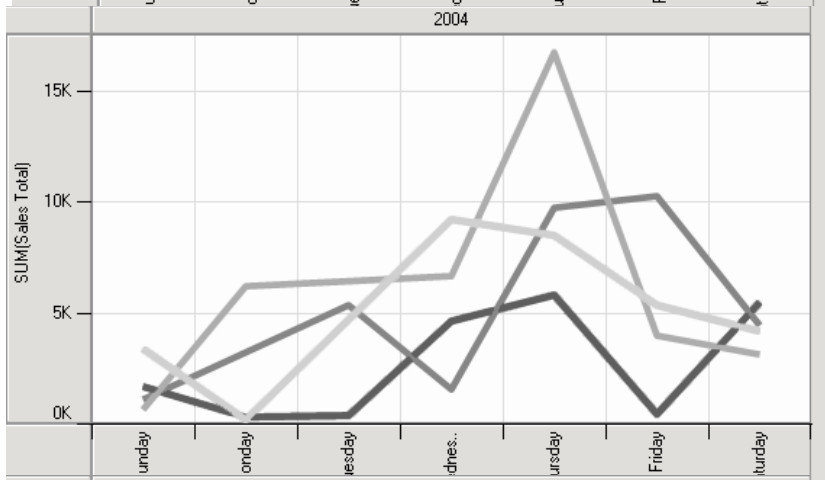
Friday


2004
Q1
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Q3
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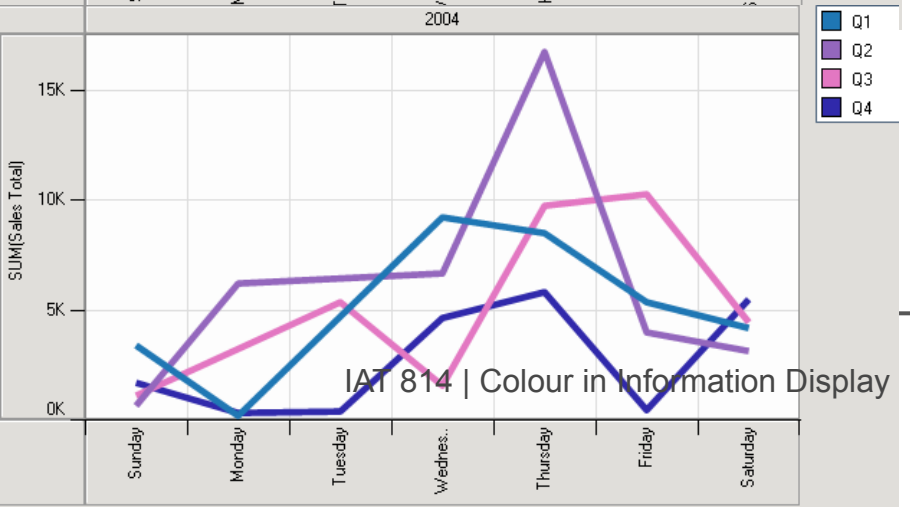
SUM(Sales Total)
15K
10K
5K
0K
Friday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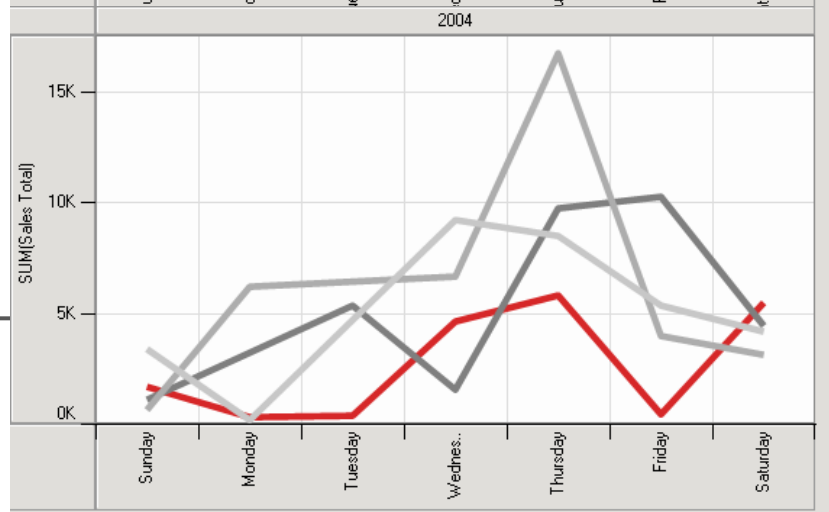

2004
Q1
Q2
Q3
Q4
SUM(Sales Total)
15K
10K
5K
0K
Sunday
Monday
Tuesday
Thursday
Friday
Saturday

Stephen Few's practical rules on charts

1. If you want different objects of the same color in a table or graph to look the same, make sure that the background—the color that surrounds them—is consistent.
2. If you want objects in a table or graph to be easily seen, use a background color that contrasts sufficiently with the object.

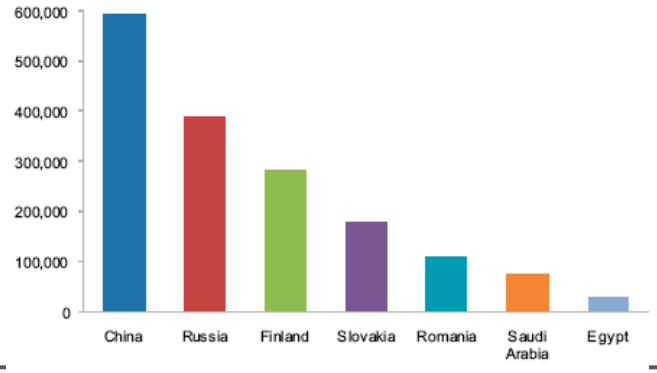
Don't do this!

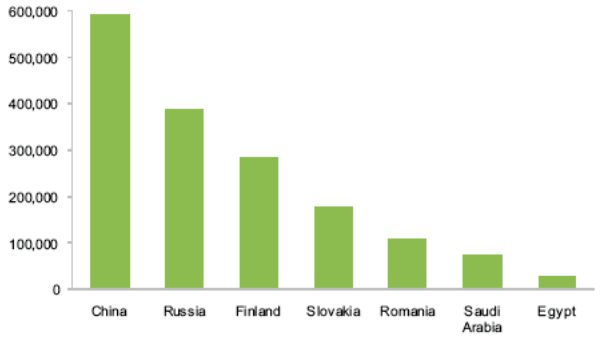
	Laptops	Desktop PCs	Harddisks	Flash Memory	Screens	Keyboards	Printers	Scanners	PDAs	Projectors	Cameras
California	-2,216	4,497	884	3,252	8,564	3,418	6,582	-3,891	2,333	1,356	5,450
Colorado	3,410	0	2,338	2,676	1,567	367	1,361	3,249	828	1,272	-141
Connecticut	0	0	4	0	2,998	1,219	673	0	0	610	989
Florida	0	0	583	765	2,305	940	1,737	2,727	0	1,344	497
Illinois	0	0	9,384	3,405	4,362	2,331	4,495	3,464	1,366	0	1,569
Iowa	377	0	412	6,577	210	4,487	872	189	5,622	0	3,466
Louisiana	0	2	1,455	1,501	1,138	0	920	1,349	0	0	991
Massachusetts	0	0	-297	0	12,489	707	0	0	0	492	367
Missouri	0	0	1,224	-169	986	367	1,011	1,125	-210	-45	-685
Nevada	0	875	374	884	-45	11,934	410	210	4,497	-10,978	4,355
New Hampshire	1,009	0	-166	0	897	376	0	0	0	882	-43
New Mexico	0	-208	-161	377	902	0	389	-683	0	0	202
New York	0	0	-17,034	0	8,564	3,254	0	0	3,405	2,326	7,589
Ohio	820	0	2,671	495	827	2,305	355	-134	2,724	0	705
Oklahoma	0	2,722	492	495	1,274	0	2,305	700	-15,034	0	571
Oregon	-139	357	818	708	395	487	2,671	834	2,310	2,727	1,269
Texas	0	1,356	3,415	808	5,452	0	2,336	1,567	0	0	829
Utah	1,130	1,006	1,501	1,009	678	-156	1,222	979	367	-208	904
Washington	0	768	488	2,998	1,661	1,452	1,418	564	918	-5	1,141
Wisconsin	497	0	1,418	1,450	576	916	767	1,740	2	0	1,337

Few (2)

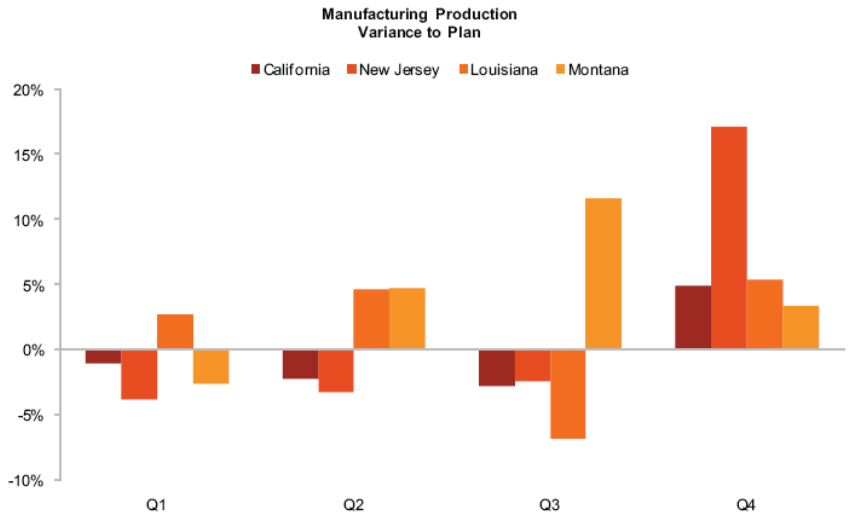
3. Use colour only when needed to serve a particular communication goal

4. Use different colours only when they correspond to differences of meaning in the data





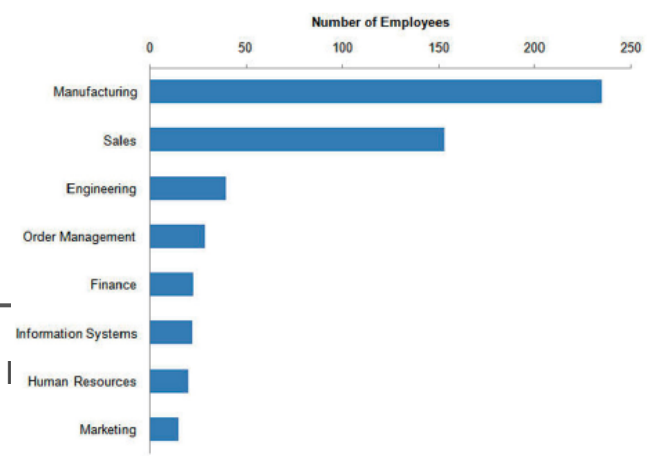
Few (3)

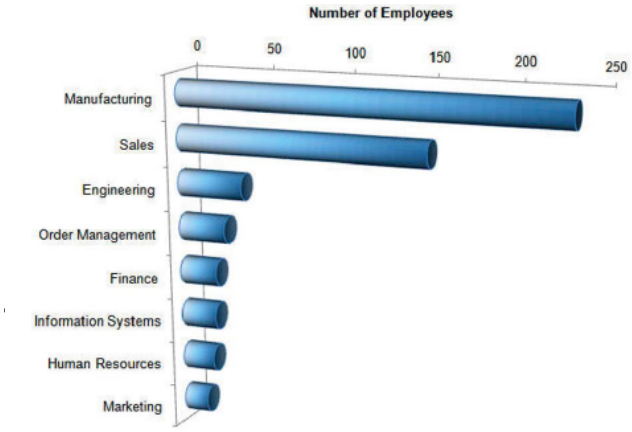


5. Use soft, natural colors to displa
   bright and/or dark colors to high
   requires greater attention.
6. When using color to encode a sequential range of quantitative values, stick with a single hue (or a small set of closely related hues) and vary intensity from pale colors for low values to increasingly darker and brighter colors for high values.

Few (4)

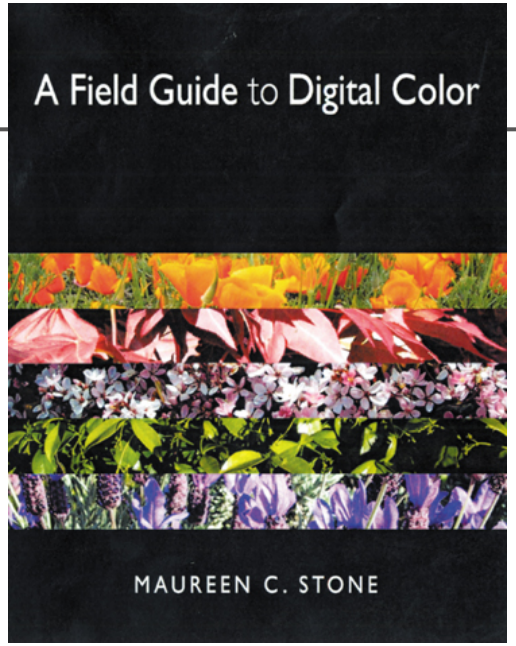
7. Non-data components of tables and graphs should be displayed just visibly enough to perform their role, but no more so, for excessive salience could cause them to distract attention from the data
8. Avoid using red/green display without redundant cueing
9. Avoid using visual effects in graphs





SFU

Additional Resources on Color



- Even without the “u” ….
- Stone Soup website
  - http://www.stonesc.com/Vis06
  - Final copy of slides, references
- *A Field Guide to Digital Color*
  - Maureen C. Stone
  - Published by A.K. Peters
- Stephen Few’s articles on color
  - http://www.perceptualedge.com