MAP COLOR AND OTHER CHANNELS

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01/01/2020

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    Direction, Rate, Frequency, ...

    

Color Theory

- Color Vision
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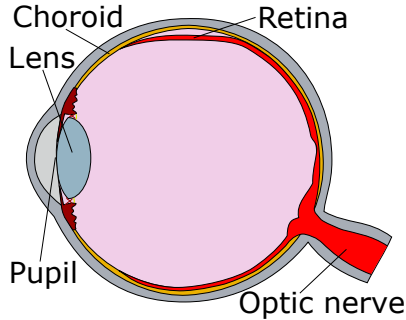
- Transparency

Color Vision

- The **retina** of the eye has two different kinds of receptors: rods, cones
- The **rods** actively contribute to vision only in low-light settings and provide low-resolution black and white information
- The main sensors in normal lighting conditions are the **cones**
- The visual system processes signals into three **opponent color channels**

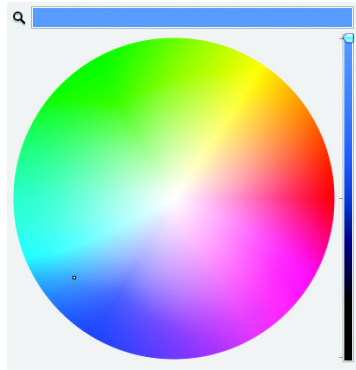


Color Spaces

- The **color space** of what colors the human visual system can detect is three dimensional; that is, it can be adequately described using three separate axes
- The most common color space in computer graphics is the system where colors are specified as triples of **r**ed, **g**reen, and **b**lue values, which is called the **RGB** system
- Another color space, the **h**ue–**s**aturation–**l**ightness or **HSL** system, is more intuitive and is heavily used by artists and designers

HSL System

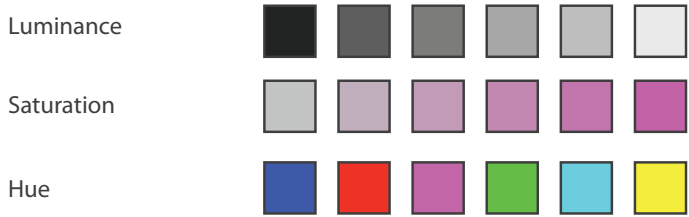
- The **hue** axis captures what we normally think of as pure colors that are not mixed with white or black: red, blue, green, yellow, purple, and so on
- The **saturation** axis is the amount of white mixed with that pure color
- The **lightness** axis is the amount of black mixed with a color



Luminance, Saturation, and Hue

Color can be confusing in vis analysis because it is sometimes used as a **magnitude channel** and sometimes as an **identity channel**

- The magnitude channel of luminance is suitable for ordered data types
- The magnitude channel of saturation is also suitable for ordered data
- The identity channel of hue is extremely effective for categorical data and showing groupings



Transparency

- A fourth channel strongly related to the other three color channels is transparency: information can be encoded by decreasing the opacity of a mark from fully opaque to completely see-through
- Transparency cannot be used independently of the other color channels
- Transparency is used most often with superimposed layers, to create a foreground layer that is distinguishable from the background layer

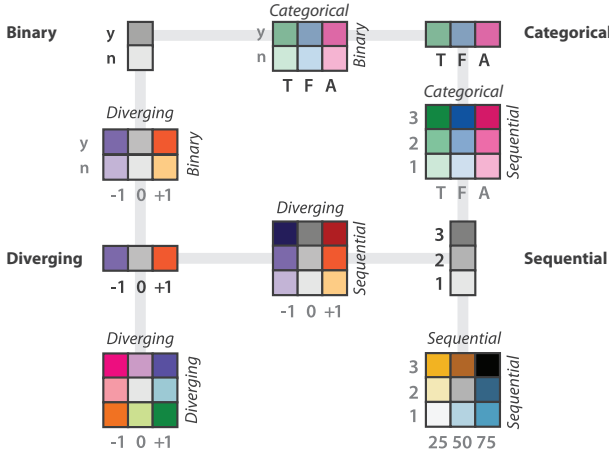
Colormaps

- Categorical Colormaps
- Ordered Colormaps
- Bivariate Colormaps
- Colorblind-Safe Colormap Design

Colormaps

- A **colormap** specifies a mapping between *colors* and *data values*
- Using color to encode data is a powerful and flexible design choice
- Colormaps can be **categorical** or **ordered**
  - ordered colormaps can be either **sequential** or **diverging**
- Colormaps can either be a **continuous** range of values, or **segmented** into discrete bins of color

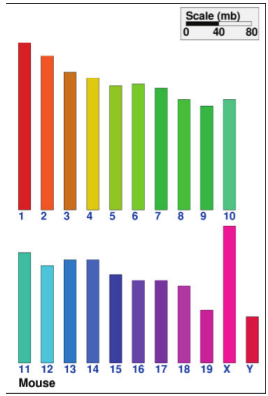
Colormaps (cont.)



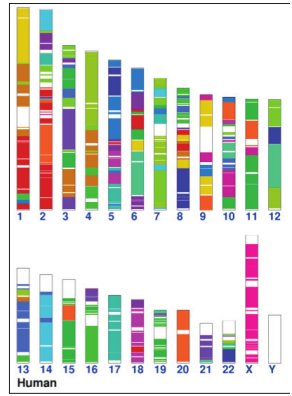
Categorical Colormaps

- A **categorical** colormap uses color to encode categories and groupings.
- Categorical colormaps are normally segmented
- Categorical colormaps are typically designed by using color as an integral identity channel to encode a single attribute
- The number of discriminable colors for coding small separated regions is limited to between six and twelve bins

Ineffective categorical colormap use



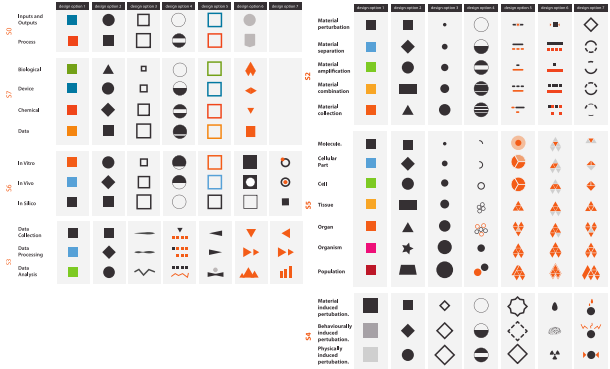
(a)



(b)

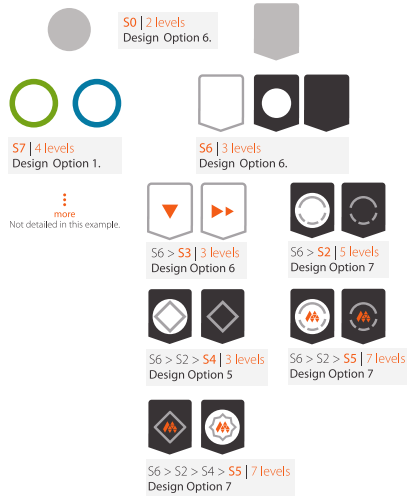
Effective categorical colormap use

- A large space of visual encoding possibilities for 27 categories was considered systematically in addition to the color channel, including size and shape channels and more complex glyphs



Effective categorical colormap use (cont.)

- The final design uses the color channel for only four of the categories



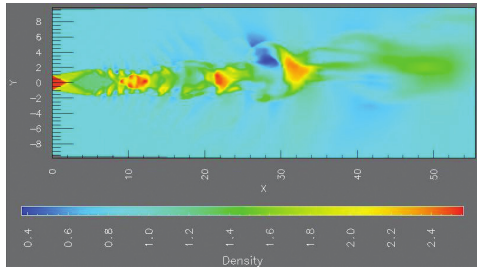
Ordered Colormaps

An **ordered** colormap is appropriate for encoding ordinal or quantitative attributes

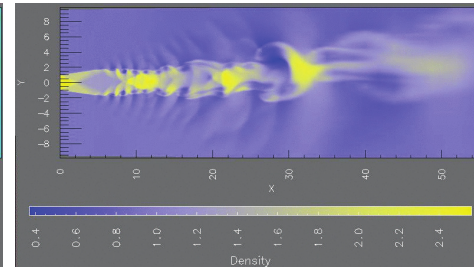
- A **sequential** colormap ranges from a minimum value to a maximum value
- A **diverging** colormap has two hues at the endpoints and a neutral color as a midpoint, such as white, gray, or black, or a high-luminance color such as yellow

Rainbow versus two-hue continuous colormap

- Many hue (**rainbow**) vs two-hue colormaps



(a)



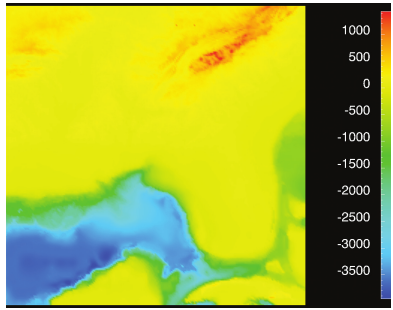
(b)

Problems with the rainbow

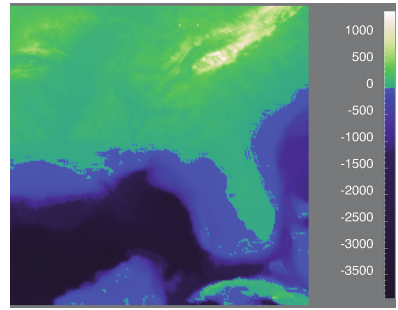
Three major problems with the common continuous rainbow colormap are

- Perceptual nonlinearity
- The expressivity mismatch of using hue for ordering
- The accuracy mismatch of using hue for fine-grained detail.

One way to address all three problems is to design **monotonically increasing luminance** colormaps



(a)



(b)

Appropriate use of rainbows

(a) The standard rainbow colormap is perceptually nonlinear.

(b) Perceptually linear rainbows are possible, but they are less bright with a decreased dynamic range.

(c) Segmented rainbows work well for categorical data when the number of categories is small.

(a)

(b)

(c)

Bivariate Colormaps

- The safest use of the color channel is to visually encode a single attribute; these colormaps are known as **univariate**.
- Colormaps that encode two separate attributes are called **bivariate**.

Colorblind-Safe Colormap Design

- Designers using color should take the common problem of **red–green color blindness** into account
- It is a sex-linked inherited trait that affects 8% of males and a much smaller proportion of females, 0.5%.

Other Channels

- Size Channels
- Angle Channel
- Curvature Channel
- Shape Channel
- Motion Channels
- Texture and Stippling

Introduction

- While the previously discussed channels pertaining to **position** and **color** are highly salient, other visual channels are also an important part of the visual encoding design space.
- Other magnitude visual channels include
  - the size channels of length, area, and volume
  - the angle/orientation/tilt channel
  - curvature
- Other identity channels are
  - shape and motion.
- Textures and stippling use combinations of multiple channels.

Size Channels

- **Size** is a magnitude channel suitable for ordered data.
- It interacts with most other channels
- **Length** is one-dimensional (1D) size
- **Area** is two-dimensional (2D) size
- **Volume** is three-dimensional (3D) size

Angle Channel

- The **angle** channel encodes magnitude information based on the **orientation** of a mark: the direction that it points
- With **angle**, the orientation of one line is judged with respect to another line
- With **tilt**, an orientation is judged against the global frame of the display

Tiltmap

(a) A sequential attribute can be shown with either a line mark or an arrow glyph in one quadrant.

(b) A diverging attribute can be shown with two quadrants and an arrow glyph.

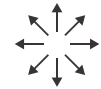
(c) A cyclic attribute can be shown with all four quadrants and arrow glyphs

Sequential ordered line mark or arrow glyph

(a)

Diverging ordered arrow glyph

(b)



Cyclic ordered arrow glyph

(c)

Curvature Channel

- The **curvature** channel is not very accurate, and it can only be used with line marks.
- It cannot be used with point marks that have no length, or area marks because their shape is fully constrained.
- The number of distinguishable bins for this channel is low, probably around two or three

Shape Channel

- The term **shape** is a catch-all word for a complex perceptual phenomenon
- Applying shape to point marks is the common case, and is easy to understand
- Applying the shape channel to line marks results in stipple patterns such as dotted and dashed lines

Motion Channels

- Several kinds of **motion** are also visual channels, including **direction** of motion, **velocity** of motion, and flicker **frequency**
- Motion is extremely salient, and more- over motion is very separable from all other static channels

Texture and Stippling

The term **texture** refers to very small-scale patterns. It is considered as the combination of three perceptual dimensions: orientation, scale, and contrast.

- Texture can be used to show categorical attributes
- Texture can also be used to show ordered attributes

The term **stippling** means to fill in regions of drawing with short strokes. It is a special case of texture.

References

Goodfellow, I., Bengio, Y., and Courville, A. (2016).
Deep learning.
MIT press.

Munzner, T. (2014).
Visualization analysis and design.
CRC press.

Russell, S. and Norvig, P. (2016).
Artificial intelligence: a modern approach.
Pearson Education Limited.

Ward, M. O., Grinstein, G., and Keim, D. (2015).
Interactive data visualization: foundations, techniques, and applications.
CRC Press.