Data Visualisation II

Gotchas

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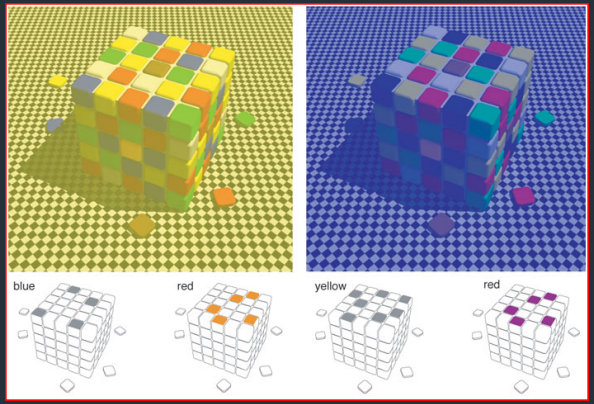
Data Visualisation II: Gotchas

- Visualisation can be tricky: Human visual perception system is full of hacks built on top of poorly-designed hardware
- What colour is the sky?
- Our visual system does not perceive all colours equally

Our brains try to be clever



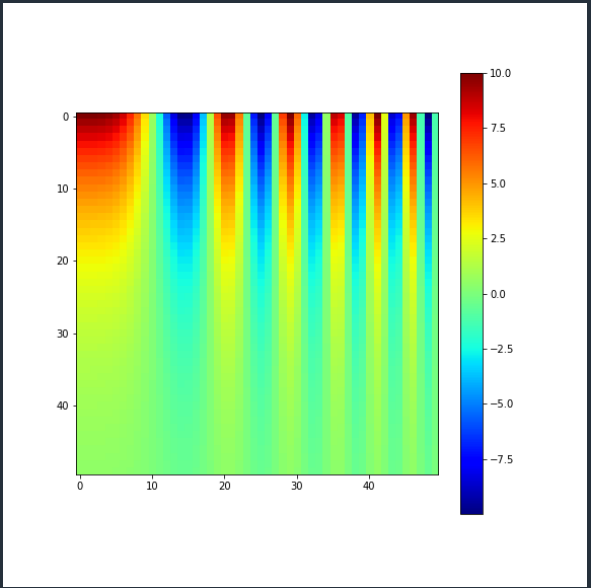
http://www.mattnewport.com/pics/colour-constancy.png

Plotting 2D data

Need to plot something with structure of various scales

```
x = np.linspace(0, 6)
y = np.linspace(0, 3)[:, np.newaxis]
z = 10 * np.cos(x ** 2) * np.exp(-y)
fig,ax = plt.subplots(1,figsize=(8,8))
ax_im = ax.imshow(z, cmap='jet')
plt.colorbar(ax_im);
```

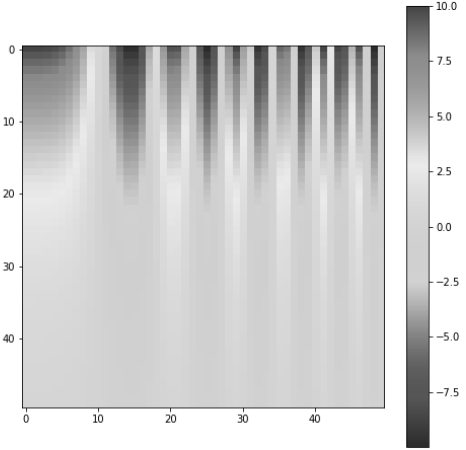
Jet colourmap



Convert to grey-scale

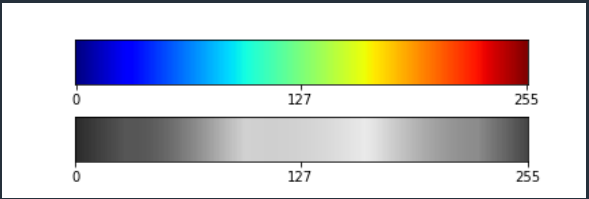
```
import matplotlib.colors as mpl_colors

def grayify_cmap(cmap):
    """Return a grayscale version of the colormap"""
    cmap = plt.cm.get_cmap(cmap)
    colors = cmap(np.arange(cmap.N))

    # convert RGBA to perceived greyscale luminance
    # cf. http://alienryderflex.com/hsp.html
    RGB_weight = [0.299, 0.587, 0.114]
    luminance = np.sqrt(np.dot(colors[:, :3] ** 2, RGB_weight))
    colors[:, :3] = luminance[:, np.newaxis]

    return mpl_colors.LinearSegmentedColormap.from_list(cmap.name +
           "_grayscale", colors, cmap.N)
```

Jet colourmap converted to grey-scale



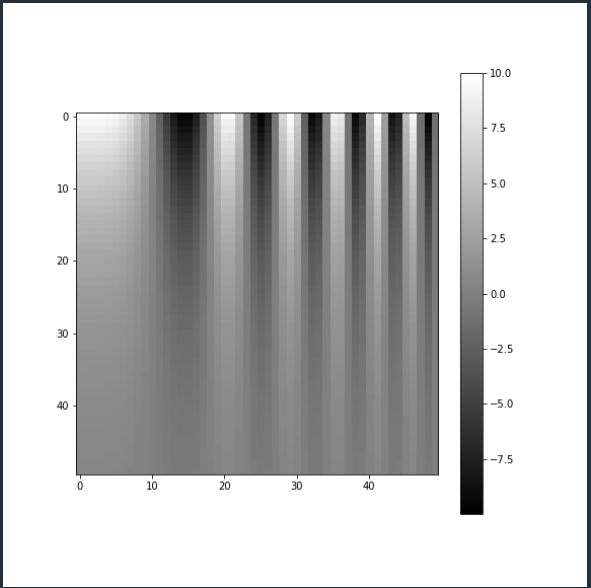
Jet colourmap

- Is this really what's happening?
- Look at colourmap converted to grey-scale:

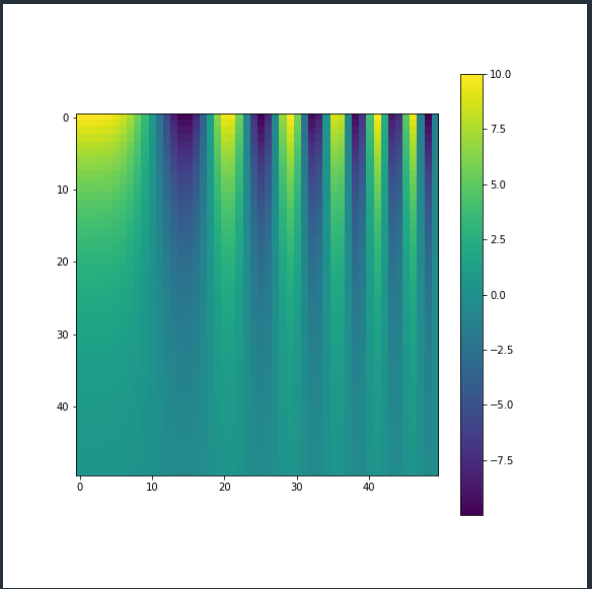


- Notice the banding?

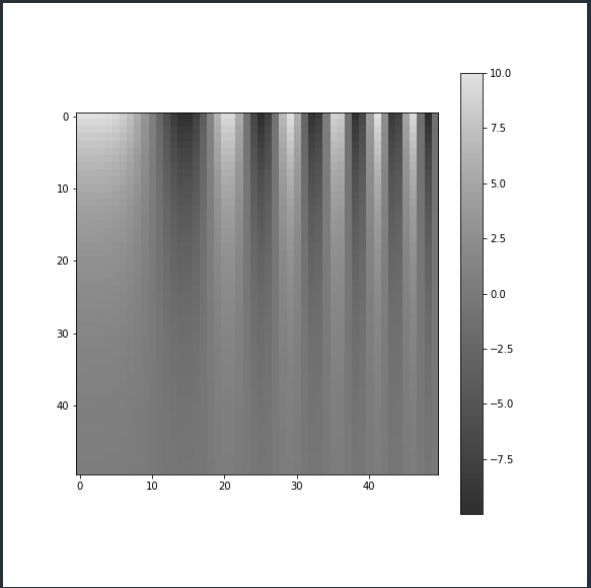
Actual grey-scale colourmap



Viridis colourmap

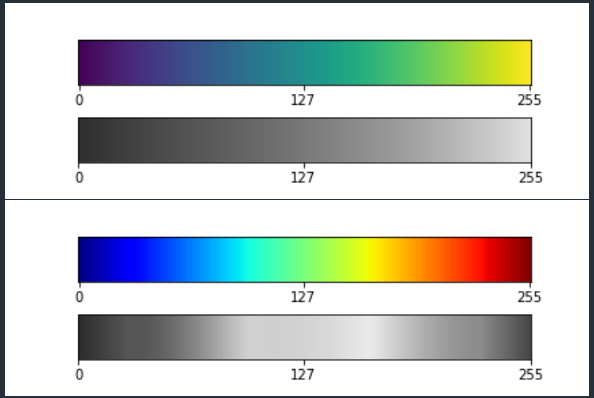


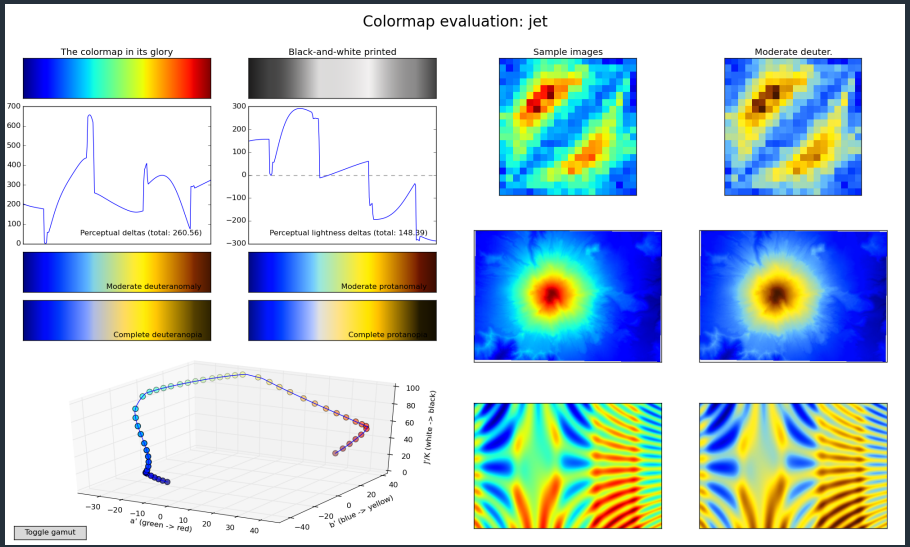
Viridis colourmap converted to grey-scale

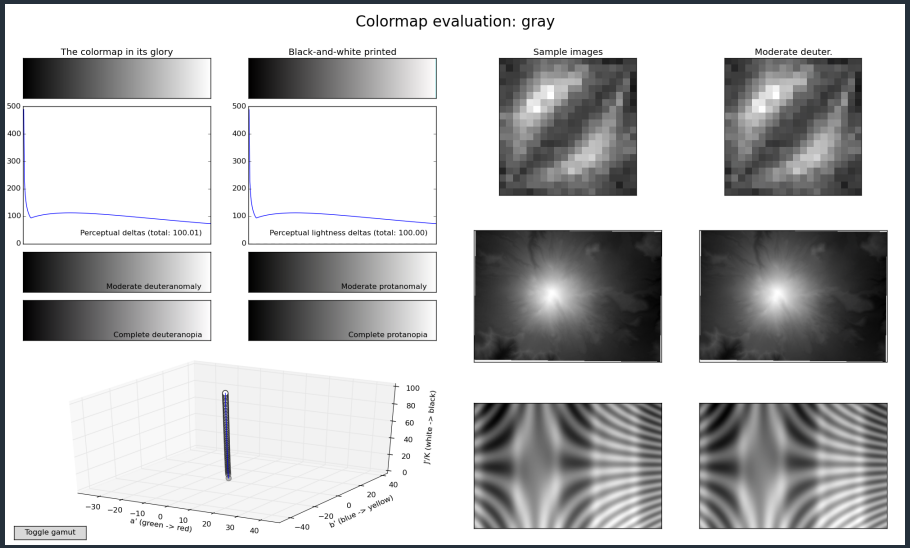


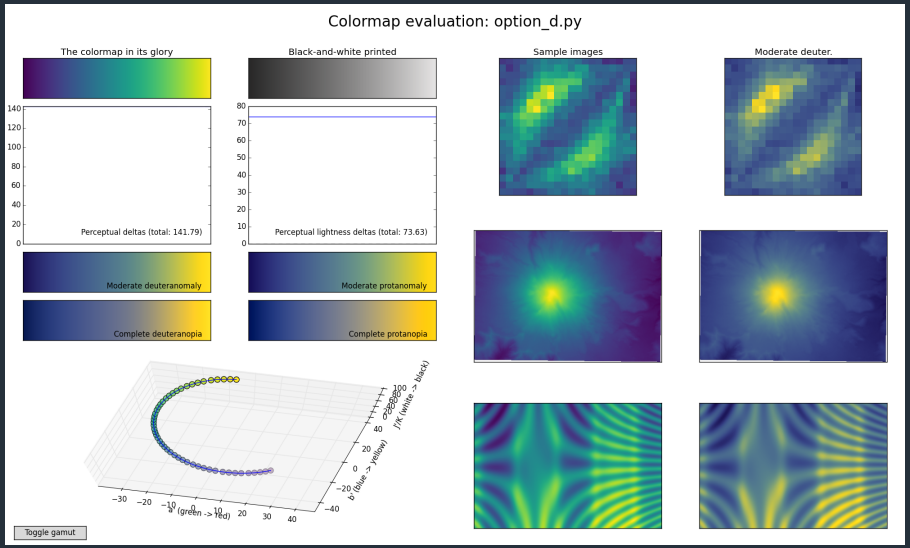
Viridis colourmap

- Compare the grey-scale versions of viridis and jet
- Imperceptible banding in viridis! “Perceptually uniform”




Colormap evaluation: jet
The colormap in its glory
Black-and-white printed
Sample images
Moderate deuter.
Perceptual deltas (total: 260.56)
Perceptual lightness deltas (total: 148.39)
Moderate deuteranomaly
Moderate protanomaly
Complete deuteranopia
Complete protanopia
J' (white -> black)
a' (green -> red)
b' (blue -> yellow)
Toggle gamut

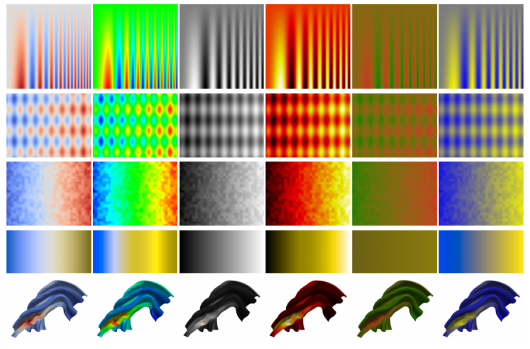

Colormap evaluation: gray
The colormap in its glory
Black-and-white printed
Sample images
Moderate deuter.
Perceptual deltas (total: 100.01)
Perceptual lightness deltas (total: 100.00)
Moderate deuteranomaly
Moderate protanomaly
Complete deuteranopia
Complete protanopia
L*/K (white -> black)
a* (green -> red)
b* (blue -> yellow)
Toggle gamut


Colormap evaluation: option_d.py
The colormap in its glory
Black-and-white printed
Sample images
Moderate deuter.
Perceptual deltas (total: 141.79)
Perceptual lightness deltas (total: 73.63)
Moderate deuteranomaly
Moderate protanomaly
Complete deuteranopia
Complete protanopia
a* (green -> red)
b* (blue -> yellow)
J'/K (white -> black)
Toggle gamut

Other pitfalls

Colour-blindness

- Affects about 8% of men, and 0.5% of women
- Various kinds, most common of which is red-green colour blindness
- Don't pick colour maps with both red and green



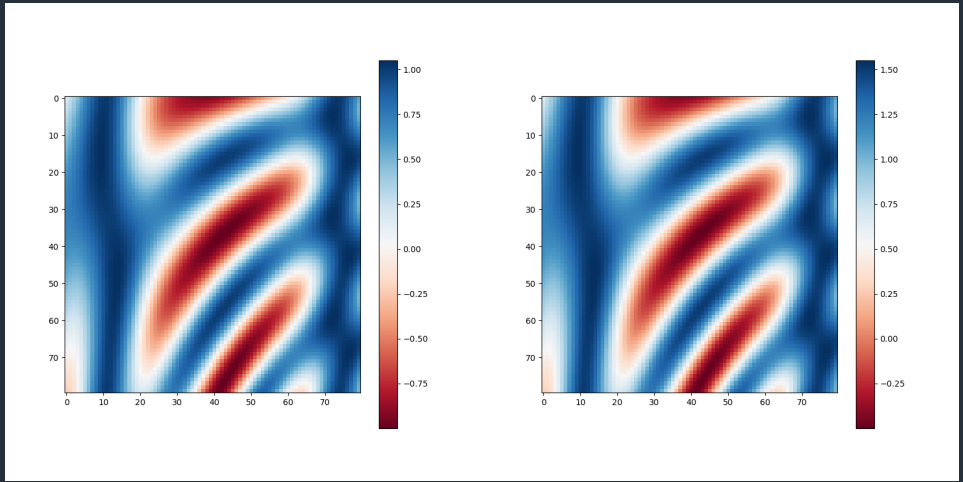
Other pitfalls

Diverging vs sequential vs qualitative datasets

- For diverging data (i.e. positive and negative values), need a good centre colour
- Paraview's default colour map is ideal and scientifically designed
- Matplotlib, "RdBu" is probably best (though has red as "negative")
- To use diverging colour schemes correctly, best to set min/max values to plus/minus the max absolute value
  - Careful with normalisations! Using the full dynamic range for both positive/negative makes the extreme values look equal in magnitude

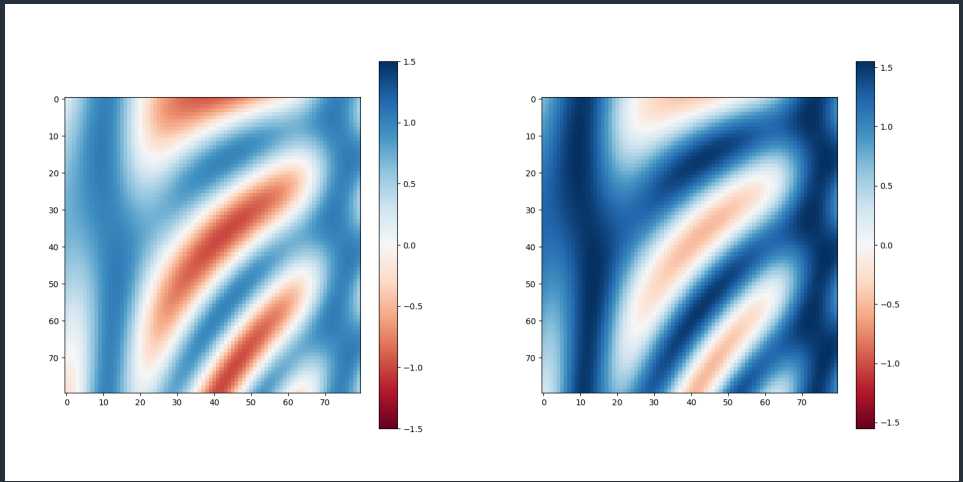
Positive and negative data

- Just plotted



Positive and negative data

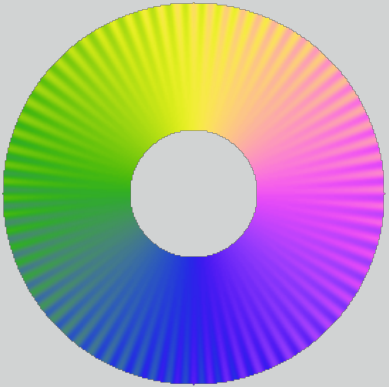
- Plotted with `+/- max(abs(f))`



Other pitfalls

Cyclic/phase colour maps

- Much trickier!
- Need to cover large area of gamut (colour space) whilst being periodic
- End up either being "washed out" or with banding
- Desirable to have "main" colours at cardinal directions
- Need to be 2D colourmap for complex plane (magnitude and phase)
- See http://peterkovesi.com/projects/colourmaps/

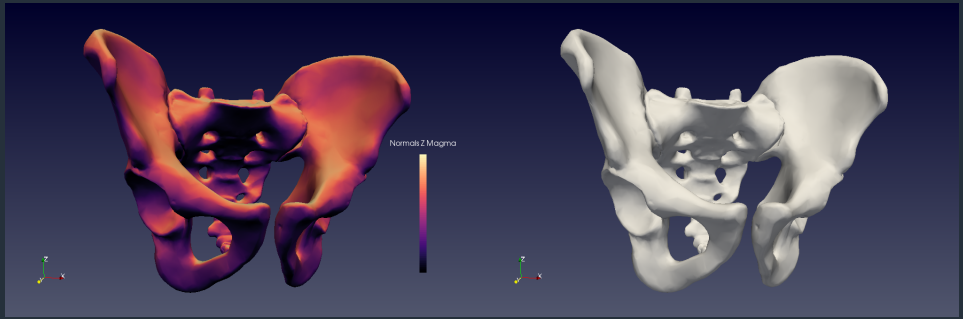


Other pitfalls

Colour maps for 3D images

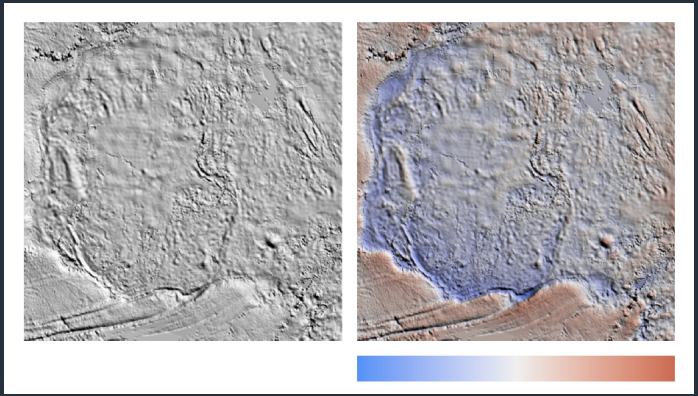
- 3D images with lighting and shading can interfere with colour maps
- Choose an “iso-luminant” colour mapping
  - Default colourmap in Paraview also designed for this
- Unfortunately, these tend to be “washed out” due to lack of saturated colours

Colour maps for 3D images



http://noeskasmit.com/colormaps-in-medical-visualization/

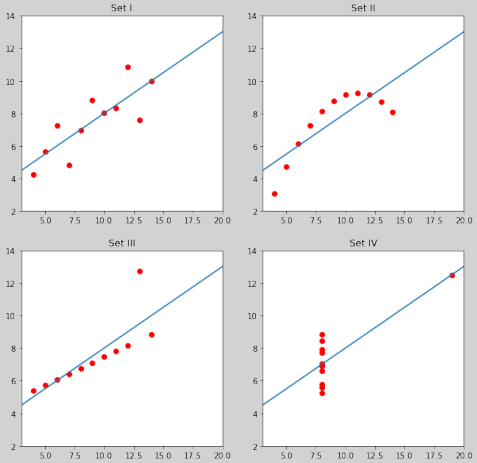
Colour maps for 3D images



Good Colour Maps: How to Design Them, Peter Kovesi, https://arxiv.org/abs/1509.03700

Plotting line graphs

Anscombe's Quartet



Plotting line graphs

Data Channels

In order of effectiveness:

- Quantitative Data:
  - Position
    - On dependent scales
    - On independent/unaligned scales
  - Length
  - Angle
  - Area
  - Depth
  - Luminance
  - Saturation
  - Curvature
  - Volume

Plotting line graphs

Data Channels

In order of effectiveness:

- Categorical Data:
  - Spatial location
  - Hue
  - Motion
  - Shape (Glyph)

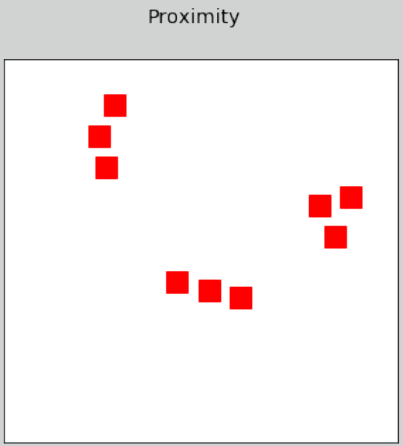
Plotting line graphs

Gestalt Principles of Perception

- Proximity - objects close to each other are seen as groups
- Similarity - objects that share channels (colour or shape for example) are seen as grouped
- Enclosure - objects enclosed by boundary and/or area are seen as grouped
- Closure - within limits, open objects are perceived as closed
- Continuity - objects that align/flow are seen as continuous objects
- Connection - objects that are connected are seen as grouped

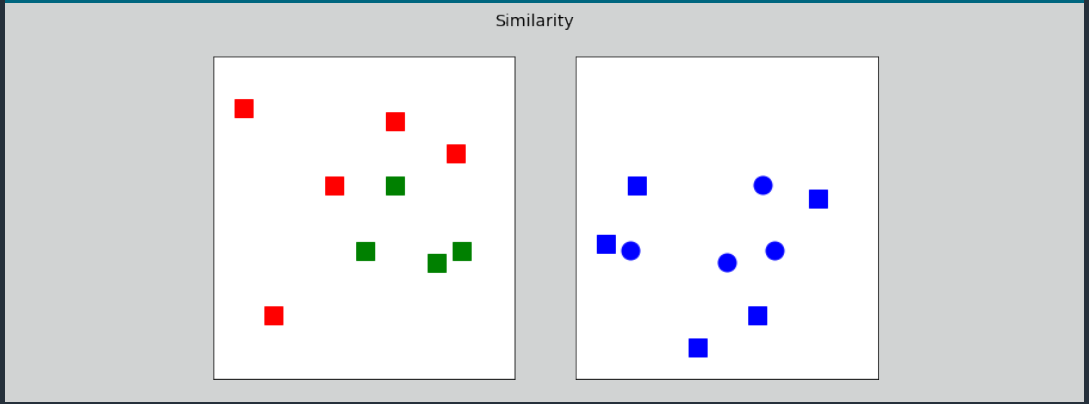
Gestalt Principles of Perception

Proximity



Gestalt Principles of Perception

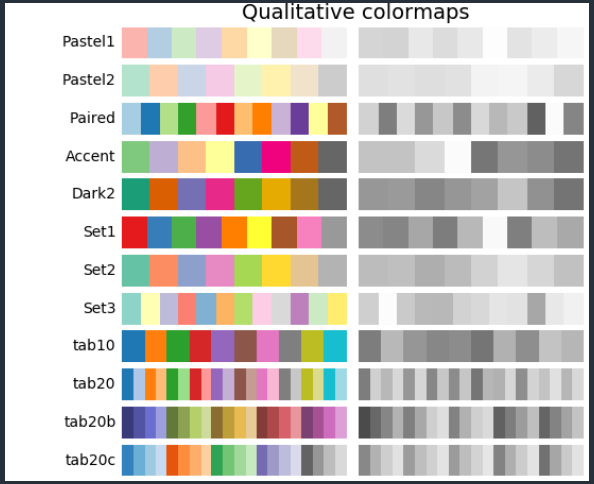
Similarity



Colours for qualitative datasets

- Cynthia Brewer designed several sets of colours for plotting cartographic data
- More generally useful though
- Designed with B&W printing, colour blindness, perceptual uniformity in mind
- https://colorbrewer2.org

Colours for qualitative datasets



https://matplotlib.org/users/colormaps.html#colormaps

Conclusions

- Upgrade to matplotlib 2.0+ if you haven't already! Has sensible defaults
- Don't use Jet or rainbow color map!
- For data with positive/negative, use a diverging colourmap
- For qualitative data, use Brewer colours

Resources

- Set of Jupyter notebooks on data visualisation: https://github.com/UoMResearchIT/data-vis-truthiness-hurts
- Brewer colours for qualitative data: https://colorbrewer2.org
- Theory of colourmaps: http://peterkovesi.com/projects/colourmaps/
- Colourmaps in Matplotlib: https://matplotlib.org/users/colormaps.html#colormaps