A Toolbox for Manipulating and Assessing Color Palettes for Statistical Graphics

Achim Zeileis, Jason C. Fisher, Kurt Hornik, Ross Ihaka, Claire D. McWhite, Paul Murrell, Reto Stauffer, Claus O. Wilke

http://colorspace.R-Forge.R-project.org/
Motivation

Map: Influenza severity in Germany (week 8, 2019).

Source: Arbeitsgemeinschaft Influenza, Robert-Koch-Institut.

Reported in: SPIEGEL Online, Tagesschau, …
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- Construction of palettes with better perceptual properties.
- Assessment of color palettes.
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Because Bob Ross would not approve of this!
Color spaces

Origin of the package: Convert colors between various three-dimensional representations of color.

In particular: From the perceptually-based HCL (Hue-Chroma-Luminance) to standard Red-Green-Blue (sRGB, and corresponding hex codes) space.
HCL vs. RGB

**HCL:** Polar coordinates in CIELUV. Captures perceptual dimensions of the human visual system very well.

Hue  (Type of color)

Chroma  (Colorfulness)

Luminance  (Brightness)
HCL vs. RGB

**HCL:** Polar coordinates in CIELUV. Captures perceptual dimensions of the human visual system very well.

**RGB:** Motivated by how computers/TVs used to generate and still represent color.

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**Hue**
- (Type of color)

**Chroma**
- (Colorfulness)

**Luminance**
- (Brightness)
HCL vs. RGB: The End of the Rainbow

RGB Spectrum

HCL Spectrum

Red / Green / Blue

Chroma / Luminance

RGB Spectrum

Hue Chroma Luminance

HCL Spectrum

Chroma / Luminance

Hue
HCL vs. RGB: The End of the Rainbow
Color palettes: Somewhere over the Rainbow

**Qualitative (Set 2)**

<table>
<thead>
<tr>
<th>Color</th>
<th>Desaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Sequential (Blues 3)**

<table>
<thead>
<tr>
<th>Color</th>
<th>Desaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Diverging (Green–Brown)**

<table>
<thead>
<tr>
<th>Color</th>
<th>Desaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualitative:
For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.

Sequential:
For ordered/numeric information, i.e., where colors go from high to low (or vice versa). Function: `sequential_hcl()`.

Diverging:
For ordered/numeric information around a central neutral value, i.e., where colors diverge from neutral to two extremes. Function: `diverging_hcl()`.
# Color palettes: Somewhere over the Rainbow

<table>
<thead>
<tr>
<th></th>
<th>Qualitative (Set 2)</th>
<th>Sequential (Blues 3)</th>
<th>Diverging (Green–Brown)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Color</strong></td>
<td><img src="image1" alt="Qualitative Colors" /></td>
<td><img src="image2" alt="Sequential Colors" /></td>
<td><img src="image3" alt="Diverging Colors" /></td>
</tr>
<tr>
<td><strong>Desaturated</strong></td>
<td><img src="image4" alt="Desaturated Colors" /></td>
<td><img src="image5" alt="Desaturated Colors" /></td>
<td><img src="image6" alt="Desaturated Colors" /></td>
</tr>
</tbody>
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Color palettes: Somewhere over the Rainbow

**Sequential:** Luminance contrast is crucial (dark to light or vice versa).

![Blues 2](image1)

![Blues 3](image2)

![Blues](image3)
**Blues 2**: Single hue. Decreasing chroma with increasing luminance.
Color palettes: Somewhere over the Rainbow

**Blues 3:** Single hue. Triangular chroma to achieve higher luminance contrast.
Color palettes: Somewhere over the Rainbow

**Blues:** Multi hue. Triangular chroma. High luminance contrast.
Color palettes: Somewhere over the Rainbow

**Diverging:** Combine two sequential palettes with balanced chroma/luminance.
**Color palettes: Somewhere over the Rainbow**

**Diverging:** Combine two sequential palettes with balanced chroma/luminance.
## Color palettes: Somewhere over the Rainbow

R> hcl_palettes(plot = TRUE)

<table>
<thead>
<tr>
<th>Qualitative</th>
<th>Greens 3</th>
<th>BluGrn</th>
<th>YIOBr</th>
<th>Blue–Red 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pastel 1</td>
<td>Oslo</td>
<td>Tea</td>
<td>OrRd</td>
<td>Blue–Red 3</td>
</tr>
<tr>
<td>Dark 2</td>
<td>Purple–Blue</td>
<td>TealGrn</td>
<td>Oranges</td>
<td>Red–Green</td>
</tr>
<tr>
<td>Dark 3</td>
<td>Red–Purple</td>
<td>EmRd</td>
<td>OrGn</td>
<td>Purple–Green</td>
</tr>
<tr>
<td>Set 2</td>
<td>Red–Blue</td>
<td>BluYl</td>
<td>YIOGrn</td>
<td>Purple–Brown</td>
</tr>
<tr>
<td>Set 3</td>
<td>Purple–Orange</td>
<td>Peach</td>
<td>YIOBu</td>
<td>Green–Brown</td>
</tr>
<tr>
<td>Warm</td>
<td>Purple–Yellow</td>
<td>PinkYl</td>
<td>YIOGnBu</td>
<td>Blue–Yellow</td>
</tr>
<tr>
<td>Cold</td>
<td>Blue–Yellow</td>
<td>Burg</td>
<td>YIOGn</td>
<td>Green–Oranger</td>
</tr>
<tr>
<td>Harmonic</td>
<td>Green–Yellow</td>
<td>BurgYl</td>
<td>YIOGn</td>
<td>Cyan–Magenta</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Red–Yellow</td>
<td>RedOr</td>
<td>YIOBr</td>
<td>Tropic</td>
</tr>
<tr>
<td>Sequential (multi–hue)</td>
<td>Heat</td>
<td>OrYel</td>
<td>Greens</td>
<td>Broc</td>
</tr>
<tr>
<td></td>
<td>Heat 2</td>
<td>Purp</td>
<td>BuGn</td>
<td>Cork</td>
</tr>
<tr>
<td></td>
<td>Terrain</td>
<td>PurpOr</td>
<td>GmBu</td>
<td>Vik</td>
</tr>
<tr>
<td></td>
<td>Terrain 2</td>
<td>Sunset</td>
<td>BuPu</td>
<td>Berlin</td>
</tr>
<tr>
<td></td>
<td>Viridis</td>
<td>Magenta</td>
<td>Blues</td>
<td>Lisbon</td>
</tr>
<tr>
<td></td>
<td>Plasma</td>
<td>Sunsd</td>
<td>Laos</td>
<td>Tofino</td>
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<tr>
<td></td>
<td>Emrld</td>
<td>ag_Sunset</td>
<td>Turku</td>
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<td>BluYl</td>
<td>ag_GrnYl</td>
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<tr>
<td>Sequential (single–hue)</td>
<td>Grays</td>
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<tr>
<td></td>
<td>Light Grays</td>
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<tr>
<td></td>
<td>Blues 2</td>
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<tr>
<td></td>
<td>Blues 3</td>
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<tr>
<td></td>
<td>Purp 2</td>
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<td>Purples 3</td>
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<tr>
<td></td>
<td>Reds 2</td>
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<td></td>
<td>Reds 3</td>
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<tr>
<td></td>
<td>Greens 2</td>
<td></td>
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</tr>
</tbody>
</table>

- **Qualitative**
  - Pastel 1
  - Dark 2
  - Dark 3
  - Set 2
  - Set 3
  - Warm
  - Cold
  - Harmonic
  - Dynamic

- **Sequential (multi–hue)**
  - Purple–Blue
  - Red–Purple
  - Red–Blue
  - Purple–Orange
  - Purple–Yellow
  - Blue–Yellow
  - Green–Yellow
  - Red–Yellow
  - Heat
  - Heat 2
  - Terrain
  - Terrain 2
  - Viridis
  - Plasma
  - Emrld
  - BluYl
  - Peach
  - PinkYl
  - Burg
  - BurgYl
  - RedOr

- **Sequential (single–hue)**
  - Green–Yellow
  - Red–Yellow
  - Heat
  - Heat 2
  - Terrain
  - Terrain 2
  - Viridis
  - Plasma
  - Emrld
  - BluYl
  - Peach
  - PinkYl
  - Burg
  - BurgYl
  - RedOr

- **Diverging**
  - Blue–Red

- **Color palettes**
  - Greens 3
  - BluGrn
  - YIOBr
  - OrRd
  - OrGn
  - YIOGnBu
  - YIOGn
  - YIOBr
  - OrRd
  - OrGn
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  - YIOGnBu
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  - YIOBr
  - OrRd
  - OrGn
  - YIOGnBu
Statistical graphics

Base:
- HCL palette functions return hex color vector.
- Typically passed to col = argument of base plotting functions.

ggplot2:
- Scales of type scale_<aesthetic>_<datatype>_<colorscale>().
- <aesthetic> is fill or color/colour.
- <datatype> is discrete or continuous.
- <colorscale> is qualitative, sequential, diverging, or divergingx.
R> q4 <- qualitative_hcl(4, palette = "Dark 3")
R> plot(log(EuStockMarkets), plot.type = "single", col = q4, lwd = 2)
R> legend("topleft", colnames(EuStockMarkets), col = q4, lwd = 3, bty = "n")

Statistical graphics: Base
R> library("ggplot2")
R> ggplot(iris, aes(x = Sepal.Length, fill = Species)) + geom_density(alpha = 0.6) +
+   scale_fill_discrete_qualitative(palette = "Dark 3")
Visualization and assessment

**Visualizations:** Based on vector of colors.

- `swatchplot()`: Color swatches.
- `specplot()`: Spectrum of HCL and/or RGB trajectories.
- `hclplot()`: Trajectories in 2-dimensional HCL space projections.
- `demoplot()`: Illustrations of typical (and simplified) statistical graphics.

**Emulation:** Color vision deficiency.

- `deutan()`: Deuteranopia (green deficient).
- `protan()`: Protanopia (red deficient).
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Visualization and assessment: `demoplot()`

R> cl <- sequential_hcl(5, palette = "Heat")
R> demoplot(cl, type = "...")
Color apps

**Facilitate exploration:** Graphical user interfaces as shiny apps.
- *Palette constructor:* `choose_palette()` or `hclwizard()` (also in tcltk).
- *Color picker:* `choose_color()` or `hcl_color_picker()`.
- *Color vision deficiency emulator:* `cvd_emulator()`.

**Online versions:** [http://hclwizard.org/](http://hclwizard.org/)
Color apps: choose_palette() / hclwizard()
Color apps: choose_color() / hcl_color_picker()
Color apps: cvd_emulator()

Severity

Different levels of severity for the color vision deficiency can be emulated. A value of 100% means maximum deficiency, a value of 0% no deficiency at all. This value has to be adjusted before uploading the image.

Upload Image

Select an image from your local disk (PNG, JPG, JPEG) for which the color vision deficiency should be emulated. Please note that the file size is limited to 50.0 Megabyte.
