A Toolbox for Manipulating and Assessing Color Palettes

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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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Problems: Color vision deficiency.
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Need tools for:

• Construction of palettes with better perceptual properties.
• Assessment of color palettes.
• Manipulation of colors.
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**Need tools for:**
- Construction of palettes with better perceptual properties.
- Assessment of color palettes.
- Manipulation of colors.

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 Color Wheel](image)

![RGB Color Wheel](image)
HCL vs. RGB: The End of the Rainbow
HCL vs. RGB: The End of the Rainbow
Qualitative (Set 2)

Color palette colors:
- Pink
- Yellow
- Green
- Light blue
- Purple

Desaturated colors:
- Light gray
- Dark gray

Sequential (Blues 3)

Color palette colors:
- Dark blue
- Blue
- Light blue
- White

Desaturated colors:
- Dark gray
- Light gray

Diverging (Green−Brown)

Color palette colors:
- Dark green
- Green
- Light green
- Brown

Desaturated colors:
- Dark gray
- Light gray

**Text:**

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

**Qualitative (Set 2)**

<table>
<thead>
<tr>
<th>Color</th>
<th>Desaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Color Palettes" /></td>
<td><img src="image2" alt="Desaturated Palettes" /></td>
</tr>
</tbody>
</table>

**Sequential (Blues 3)**

<table>
<thead>
<tr>
<th>Color</th>
<th>Desaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Color Palettes" /></td>
<td><img src="image4" alt="Desaturated Palettes" /></td>
</tr>
</tbody>
</table>

**Diverging (Green–Brown)**

<table>
<thead>
<tr>
<th>Color</th>
<th>Desaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5" alt="Color Palettes" /></td>
<td><img src="image6" alt="Desaturated Palettes" /></td>
</tr>
</tbody>
</table>

**Qualitative**: For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.
**Color palettes: Somewhere over the Rainbow**

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

- **Blues 2**
- **Blues 3**
- **Blues**
**Color palettes: Somewhere over the Rainbow**

**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.
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Color palettes: Somewhere over the Rainbow

R> hcl_palettes(plot = TRUE)

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

**Sequential (multi-hue)**
- Greens 3
- BlueGrn
- BluGrn
- YeOrBr
- Blue–Red 2
- Blue–Red 3
- OrRd
- OrGrn
- Red–Green

**Sequential (single-hue)**
- Grays
- Light Grays
- Blues 2
- Blues 3
- Purples 2
- Purples 3
- Reds 2
- Reds 3
- Greens 2
- Mint

**Diverging**
- BluGrn
- TealGrn
- Emrld
- BluYl
- ag_GrnYl
- YlGrn
- YrGn
- YlOrBr
- Blue–Red 2
- Blue–Red 3
- OrRd
- OrGrn
- Red–Green
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")
R> ttnc <- margin.table(Titanic, c(1, 4))[, 2:1]
R> spineplot(ttnc, col = sequential_hcl(2, palette = "Purples 3"))
R> library("ggplot2")
R> ggplot(iris, aes(x = Sepal.Length, fill = Species)) + geom_density(alpha = 0.6) +
  +  scale_fill_discrete_qualitative(palette = "Dark 3")
R> dsamp <- diamonds[1 + 1:1000 * 50, ]
R> ggplot(dsamp, aes(carat, price, color = cut)) + geom_point() +
  +   scale_color_discrete_sequence(palette = "Purples 3", nmax = 6, order = 2:6)
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.
Visualization and assessment: `hclplot()`

R> `hclplot(qualitative_hcl(7, palette = "Set 2"))`
R> `hclplot( sequential_hcl(7, palette = "Blues 3"))`
R> `hclplot( diverging_hcl(7, palette = "Blue-Red"))`
Visualization and assessment: `demoplot()`

```r
R> cl <- sequential_hcl(5, palette = "Heat")
R> demoplot(cl, type = "...")
```
Color vision deficiency

**Emulate:** Color vision deficiencies.
- **deutan:** Deuteranopia (green deficient).
- **protan:** Protanopia (red deficient).
- **tritan:** Tritanopia (blue deficient).

**Example:** Maunga Whau volcano data.
Color vision deficiency

rainbow(11, end = 2/3)

sequential_hcl(11, "Blue-Yellow")
Approximations of other palettes

ColorBrewer.org: YlGnBu

ColorBrewer.org: Viridis
Approximations of other palettes

ColorBrewer.org: YlGnBu

Viridis
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 disc (PNG/JPG/JPEG) for which the color vision deficiency should be emulated. Please note that the file size is limited to 50.0 Megabyte.
In 3.6.0: All prespecified palettes also via `grDevices::hcl.colors()`.
Base R: Why you might not need our package after all

In 3.6.0: All prespecified palettes also via grDevices::hcl.colors().
Recommendations

Colors and palettes:

- Do not overestimate the effectiveness of color.
- Choose type of palette based on the data to be visualized.
- For areas use light colors (higher luminance, lower chroma).
- For points/lines darker colors are needed (lower luminance, higher chroma).
- For palettes with more colors stronger luminance contrasts are needed.
- Triangular chroma trajectories useful for distinguishing central colors.

R packages:

- `colorspace` facilitates exploration, manipulation, and assessment.
- HCL approximations of palettes from `RColorBrewer`, `rcartocolor`, `scico`, ...
- Prespecified palettes are also easily available in base R.
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