Choosing Color Palettes for Data Visualization
Tools and Technologies for Supporting Algorithm Fairness and Inclusion

Achim Zeileis
https://www.zeileis.org/
Motivation

Colors in data visualization:

- Ubiquitous.
- Not always easy to choose.
- But also perceived as fun.
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Potential problems:
- Power of color often overestimated.
- Color vision deficiencies (~8% of male and ~0.5% of female viewers).
- Other physical or technical limitations.
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Illustration: Time series line plot using base graphics.

```r
R> p <- c(1:3, 5)
R> plot(EuStockMarkets, log = "y", plot.type = "single", col = p, ...)
R> legend("topleft", colnames(EuStockMarkets), col = p, ...)
```
Motivation

Palette: $R \leq 3$ default
Emulation: None
Labeling: Legend
Motivation

Palette: R ≤ 3 default
Emulation: None
Labeling: Legend
Comments:
Too flashy
Cyan too light
Motivation

Palette: $R \leq 3$ default
Emulation: Protanope
Labeling: Legend

Comments:
Too flashy
Cyan too light
Hard to distinguish for protanope viewers
Motivation

Palette: $R \leq 3$ default
Emulation: Protanope
Labeling: Direct

Comments:
Too flashy
Cyan too light
Hard to distinguish for protanope viewers
Motivation

Palette: $R \leq 3$ default
Emulation: None
Labeling: Direct

Comments:
Too flashy
Cyan too light
Hard to distinguish for protanope viewers
Motivation

Palette: $R \geq 4$ default
Emulation: None
Labeling: Direct

Comments:
- Similar hues
- More balanced brightness
- Avoid garish colors
Motivation

Palette: R ≥ 4 default
Emulation: Protanope
Labeling: Direct

Comments:
Similar hues
More balanced brightness
Avoid garish colors
Motivation

Palette: Okabe-Ito
Emulation: None
Labeling: Direct

Comments:
Designed to be robust against color vision deficiencies
Motivation

Palette: Okabe-Ito
Emulation: Protanope
Labeling: Direct

Comments:
Designed to be robust against color vision deficiencies
Motivation

Source: Mara Averick via Twitter
Motivation

**Base R:** Neglected better color palettes for a long time.

**Earlier packages:** RColorBrewer, colorspace, ggplot2, viridis, rcartocolor, Polychrome, scico, pals, paletteer, ... 

**Thus:** Many good palettes easily available.

Source: Mara Averick via Twitter
Motivation

Qualitative (palette.colors)

R4

ggplot2

Okabe-Ito

Accent

Dark 2

Paired

Pastel 1

Pastel 2

Set 1

Set 2

Set 3

Tableau 10

Classic Tableau

Polychrome 36

Alphabet
Motivation

R> palette.colors(palette = "R4") |>  
+   colorspace::swatchplot(cvd = TRUE)
Motivation

```r
R> palette.colors(palette = "Okabe-Ito") |> 
+   colorspace::swatchplot(cvd = TRUE)
```

<table>
<thead>
<tr>
<th></th>
<th>Original</th>
<th>Deuteranope</th>
<th>Protanope</th>
<th>Tritanope</th>
<th>Desaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
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</table>
Color palette construction

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

- **Hue** (Type of color)
- **Chroma** (Colorfulness)
- **Luminance** (Brightness)
**HCL:** Polar coordinates in CIELUV. Captures perceptual dimensions of the human visual system very well.

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

<table>
<thead>
<tr>
<th>Hue (Type of color)</th>
<th>Red</th>
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<tbody>
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</table>

<table>
<thead>
<tr>
<th>Chroma (Colorfulness)</th>
<th>Green</th>
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<table>
<thead>
<tr>
<th>Luminance (Brightness)</th>
<th>Blue</th>
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<tbody>
<tr>
<td>Color palette construction</td>
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<td>---------------------------</td>
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<tr>
<td><strong>Qualitative (Set 2)</strong></td>
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<tr>
<td>Color</td>
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<tr>
<td>Desaturated</td>
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<tr>
<td><strong>Sequential (Blues 3)</strong></td>
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<tr>
<td>Color</td>
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<td>Desaturated</td>
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<tr>
<td><strong>Diverging (Green–Brown)</strong></td>
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<tr>
<td>Color</td>
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<tr>
<td>Desaturated</td>
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</tbody>
</table>

- **Qualitative:** For categorical information with no particular ordering. Luminance differences should be limited.
- **Sequential:** For ordered/numeric information from high to low (or vice versa).
- **Diverging:** For ordered/numeric information diverging from a central neutral value to two extremes.
Color palette construction

**Qualitative (Set 2)**
- Color:
  - Pink
  - Yellow
  - Green
  - Blue
  - Purple
- Desaturated:
  - Light gray
  - Dark gray

**Sequential (Blues 3)**
- Color:
  - Dark blue
  - Medium blue
  - Light blue
  - White
- Desaturated:
  - Light gray
  - Dark gray

**Diverging (Green−Brown)**
- Color:
  - Dark green
  - Medium green
  - Light green
  - Light brown
  - Brown
- Desaturated:
  - Light gray

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Color palette construction

Sequential (hcl.colors)

Diverging (hcl.colors)
Risk maps and communication to the public

**Risk map:** Probability of wind speeds $>39$ mph ($63 \text{ km h}^{-1}$), 2019-08-30–2019-09-04

**Source:** National Oceanic and Atmospheric Administration (noaa.gov)
Risk maps and communication to the public

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Risk maps and communication to the public

Source: White House (2019-09-04)

Source: U.S. president via Twitter (2019-09-05)
Colors by designers, painters, and directors?

**Movie:** *Todo sobre mi madre* (All About My Mother, 1999)

**Source:** Sony Pictures Classics via MoMA
Colors by designers, painters, and directors?

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**Palette:** Hadley Mendelsohn
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Colors by designers, painters, and directors?

Palette: Todo sobre mi madre
Colors by designers, painters, and directors?

Palette: OrRd (ColorBrewer.org, HCL version)
Colors by designers, painters, and directors?

Movie: *Tacones lejanos* (High Heels, 1991)

Source: El Deseo S.A. via Twitter
Colors by designers, painters, and directors?

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Palette: Bibiana Fernandez
Colors by designers, painters, and directors?

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Wrap-up

Tools:

- *grDevices*: `palette.colors()`, `hcl.colors()`.
- *colorspace*: `swatchplot(...)`, `cvd = TRUE`.
- Interactive shiny apps on [https://www.hclwizard.org/](https://www.hclwizard.org/).
Wrap-up

Tools:
• \textit{grDevices}: \texttt{palette.colors()}, \texttt{hcl.colors()}.
• \textit{colorspace}: \texttt{swatchplot(..., cvd = TRUE)}.
• Interactive shiny apps on \url{https://www.hclwizard.org/}.

Strategy:
• Check whether color is appropriate for coding your information.
• Use appropriate type of palette.
• Don’t reinvent the wheel, start out from well-established palettes.
• Check robustness of palette.
• Be careful with palettes with too much chroma.
References


Web: https://colorspace.R-Forge.R-project.org/
Twitter: @AchimZeileis