Generating Colors from the Viridis Color Scale with a SAS® Macro

Shane Rosanbalm, Rho, Inc.

ABSTRACT

In this paper we present a SAS® macro capable of producing a list of RGB color values from the Viridis color scale. The Viridis color scale was originally designed for MATLAB® as an open-source alternative to MATLAB's proprietary Parula color scale, which itself was a replacement for the oft criticized Jet color scale.

Viridis is designed to be:

- **Colorful**, spanning as wide a palette as possible so as to make differences easy to see,

- **Perceptually uniform**, meaning that values close to each other have similar-appearing colors and values far away from each other have more different-appearing colors, consistently across the range of values,

- **Robust to colorblindness**, so that the above properties hold true for people with common forms of colorblindness, as well as in grey scale printing, and

- **Pretty**, oh so pretty.

INTRODUCTION

Color scales are commonly used to represent the value of some 3rd variable in a two-dimensional graphic. In this example from the SGPLOT gallery, color represents cost.
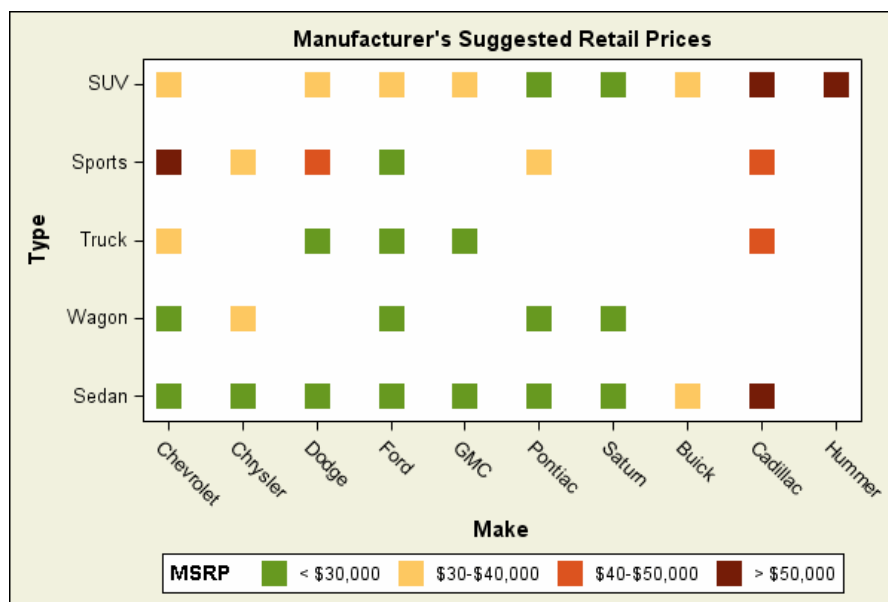

Figure 1. Color indicates MSRP by Make and Type

There are many color scales to choose from, but how does one choose a "good" color scale? What criteria make a color scale "good"?

MATLAB ORIGINS

The Viridis color scale has its origins in MATLAB. Users Stéfan van der Walt and Nathaniel Smith were unsatisfied with the default Jet color scale. As they argue in their SciPy 2015 presentation, Jet is not perceptually uniform (the wild fluctuations in the line chart on the left), does not print well in grayscale (the wild fluctuations in the line chart on the right), and is not robust to colorblindness (the four strips at bottom).
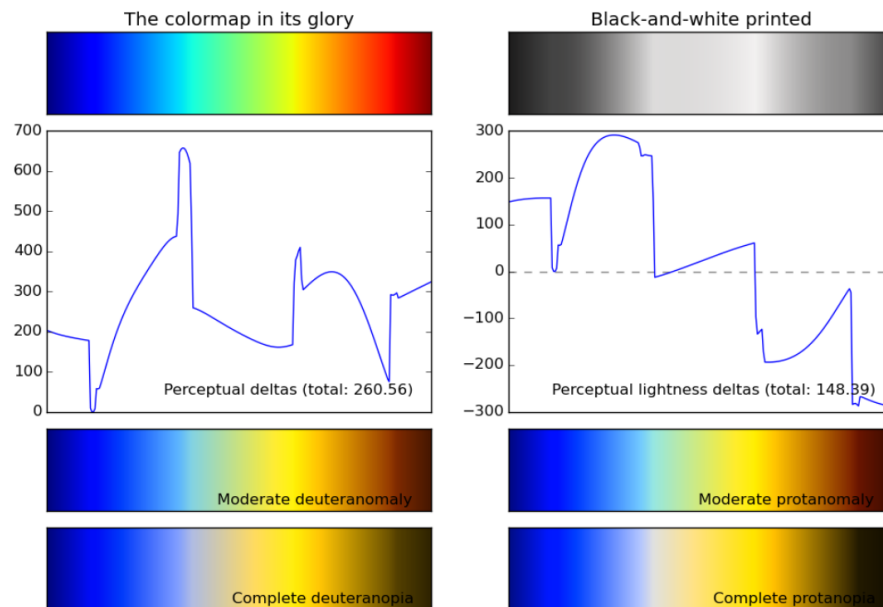
Figure 2. Properties of the Jet color scale

In response to longstanding complaints about Jet, MATLAB published a replacement color scale called Parula. This new scale is much more perceptually uniform (less fluctuation in the line chart on the left), prints better in grayscale (less fluctuation in the line chart on the right), and is more robust to colorblindness (the four strips at the bottom).
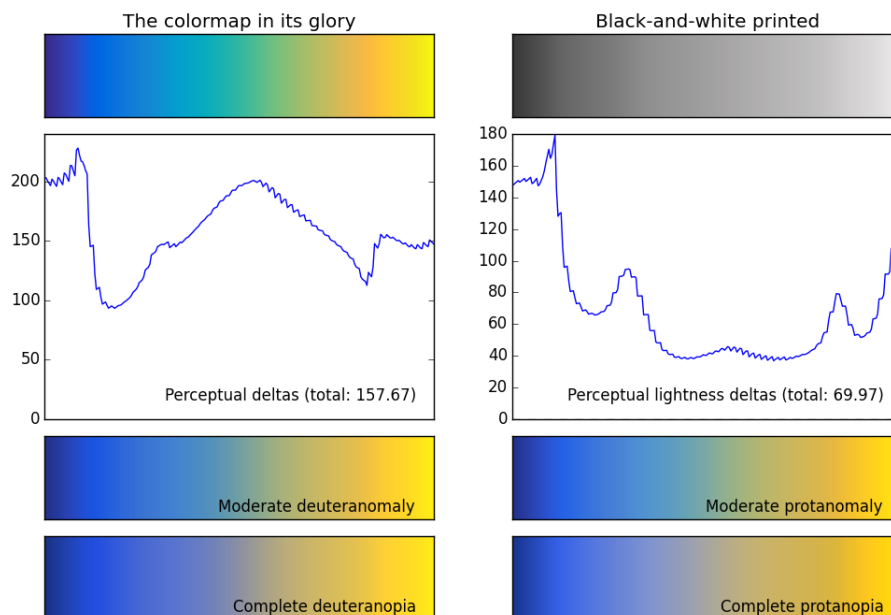
Figure 3. Properties of the Parula color scale

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Unfortunately for non-MATLAB users, Parula is proprietary. This restriction did not sit well with van der Walt and Smith. The pair set about trying to create an open-source alternative to Parula. They came up with the following criteria for a "good" color scale:

- **Colorful**, spanning as wide a palette as possible so as to make differences easy to see,

- **Perceptually uniform**, meaning that values close to each other have similar-appearing colors and values far away from each other have more different-appearing colors, consistently across the range of values,

- **Robust to colorblindness**, so that the above properties hold true for people with common forms of colorblindness, as well as in grey scale printing, and

- **Pretty**, oh so pretty.

Using lots of color theory and complex mathematics, the pair eventually invented a color scale that they named Viridis.
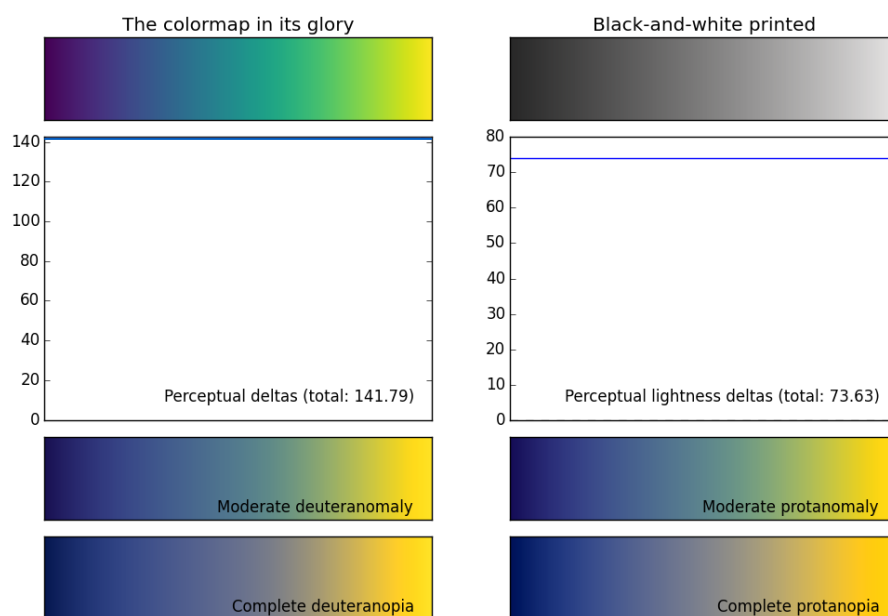

Figure 4. Properties of the Viridis color scale

It's hard to see the blue line in the top left graph because it is right up against the border, but the perceptual deltas are completely uniform across the entire range of the color scale (141.79). The black-and-white deltas are likewise constant. The colorblind simulations look nice as well. And as an added bonus, it's open-source.

VIRIDIS GAINS IN POPULARITY

Viridis was quickly adopted by the R community. In 2016 authors Bob Rudis, Noam Ross, and Simon Garnier published the viridis package, an R-based implementation of the viridis color scale. On the corresponding r-project page they include several nice examples of viridis in action, including the following heat map of randomly-generated bivariate normal data.
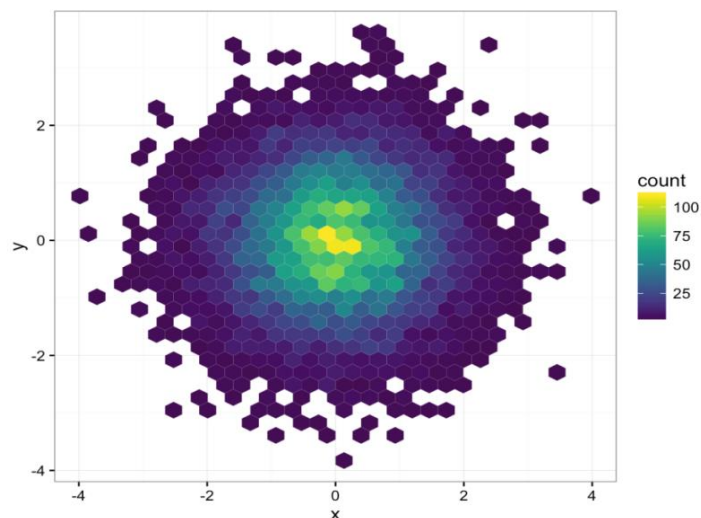
Figure 5. Viridis color scale used in a heat map in R

COLOR BREWER AND %BREWERPAL

The Viridis colors are not yet well known among SAS programmers. The current color source of first resort is the Color Brewer website. The site's interactive menus (top left) assist in the selection of appropriate sets of colors for graphical outputs. The following image depicts a 9-color model from the sequential Yellow-Green-Blue scale.
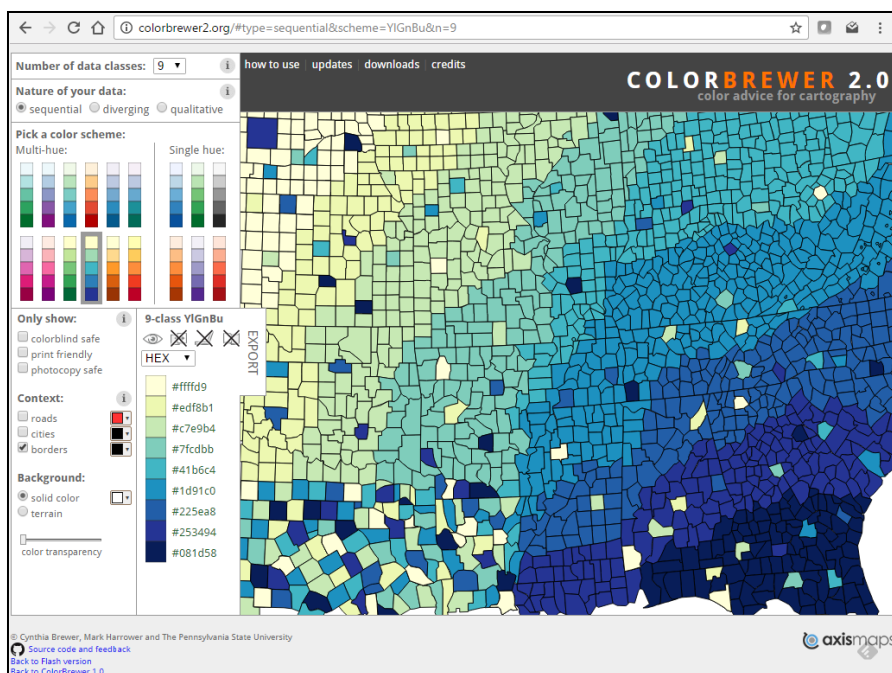

Figure 6. A sequential color scale from Color Brewer

SAS programmer Michael Friendly created a macro called %brewerpal to make it easier to generate lists of colors from the various Brewer scales. Instead of using copy-and-paste to transfer color names from the website, the %brewerpal macro generates a list of colors in the form of a macro variable. A stripped-down example follows.

```
%brewerpal(n=4, palette=YlGnBu, result=brewer4);

proc sgplot;
   styleattrs datacontrastcolors=(&brewer4);
   series ...
run;
```
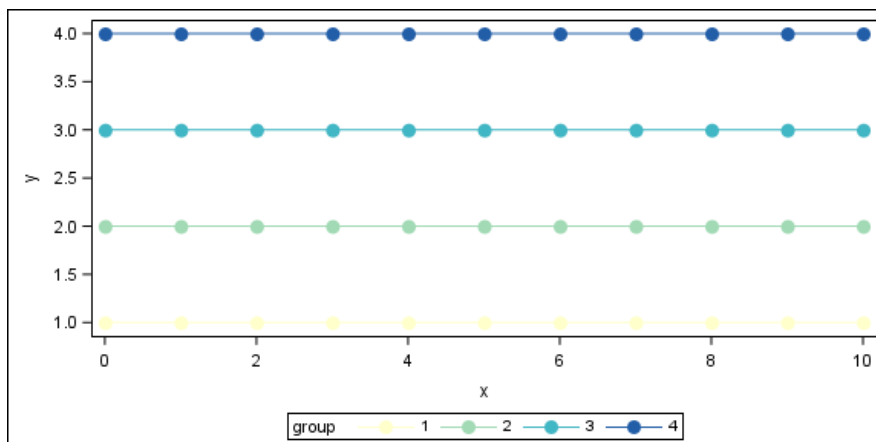

Figure 7. Using the %brewerpal macro to generate colors

THE %VIRIDIS MACRO

The %viridis macro was created with the goal of making it easy for SAS users to start using Viridis colors in their graphical outputs. The design of the macro uses %brewerpal as an inspiration. Because there is only one Viridis scale the typical %viridis macro call is fractionally leaner than the typical %brewerpal macro call. A stripped-down example follows.

```
%viridis(n=4);

proc sgplot;
   styleattrs datacontrastcolors=(&viridis4);
   series ...
run;
```
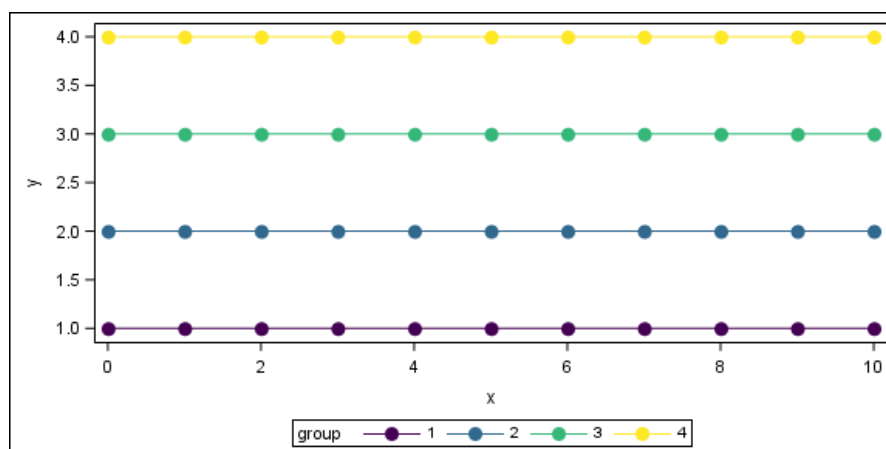

Figure 8. Using the %viridis macro to generate colors

The only required parameter for the %viridis macro is n=: the number of colors that the macro should return. By default the macro begins at the purple end of the scale and moves in even steps to the yellow end of the scale. Some optional parameters exist that allow for modifications of this default behavior.
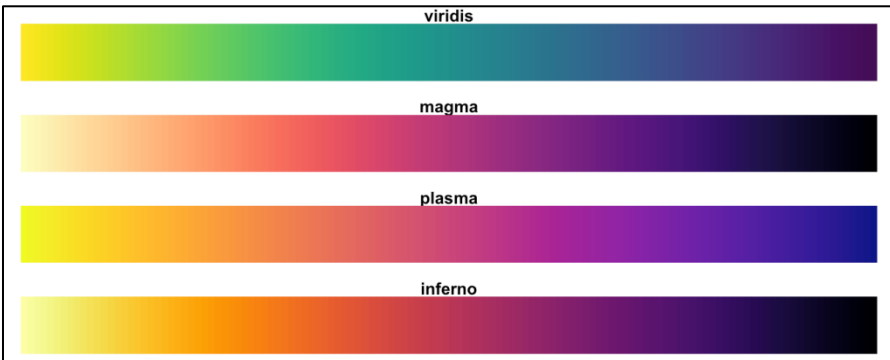
Parameter	Description
n	Number of colors to return. VALID: integers from 2-256
palette	Palette from which to select the colors. VALID: viridis | magma | plasma | inferno DEFAULT: viridis Note: The viridis authors actually published 4 different color scales as part of a package. The "best" of those was chosen as the namesake. All 4 palettes are available in this macro.
greyscale	Convert colors to greyscale using the luma formula. VALID: yes | no DEFAULT: no Note: Useful for when you are not allowed to use color in your graphics.
reverse	Provide colors in reverse order. VALID: yes | no DEFAULT: no Note: The default order is dark (purple) to light (gold). Perhaps you would prefer going from light to dark on occasion.
result	Name of macro variable containing colors as a space-separated list. DEFAULT: viridis&n (actually &palette&n)
out	Name of output dataset with one observation per color. DEFAULT: work.palette

Table 1. %viridis macro parameters

Here is an example of how one might use some of the optional parameters of the %viridis macro in a heat map application.

```
%viridis(n=256, palette=plasma, result=tengocalor);

proc sgplot data=plotdata;
  heatmap x=x y=y / colormodel=(&tengocalor);
run;
```
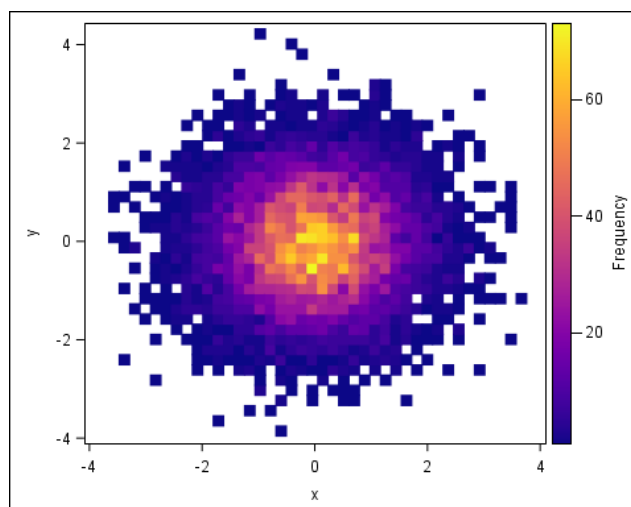
Figure 9. Using the %viridis macro in a heat map

WHEN TO (AND NOT TO) USE VIRIDIS COLORS

The Viridis color scale is best suited to when color can be used to represent a range of values (heat maps, medical imaging, temperature data, etc.). It also works nicely as a grouping variable when the groups are easily ordered (pH, ascending dose groups, categorized treatment response, etc.).

Viridis colors are less appropriate when dealing with categorical data that has no natural order (when data is grouped by country, company, department, etc.) as such applications erroneously imply a continuum of values. Qualitative color scales are more appropriate for non-ordered categories. Many of the built-in SAS styles utilize qualitative color scales. The Color Brewer website is also a good source of qualitative color scales.

DOWNLOAD

To get started with the %viridis macro, visit http://github.com/rhoinc/sas-viridis. Click on the shiny "Clone or download" button and select the "Download ZIP" option.
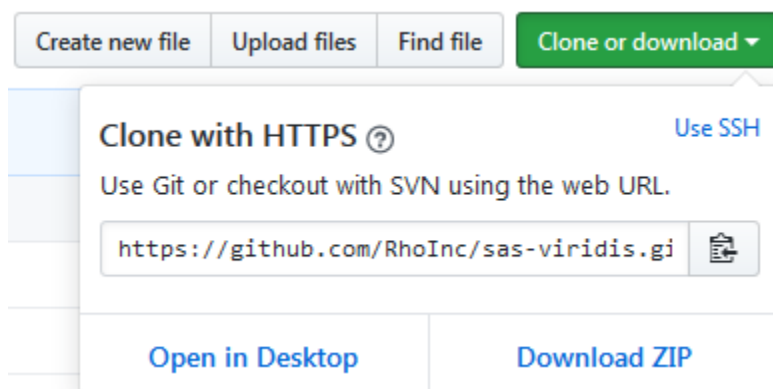

Figure 10. Downloading the %viridis macro from GitHub

CONCLUSION

The viridis color scale was designed to be colorful, perceptually uniform, robust to colorblindness, and oh so pretty. The %viridis macro makes it easy for SAS programmers to select colors from this scale and use them in graphics applications. Enjoy!

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CONTACT INFORMATION

Your comments and questions are valued and encouraged. Contact the author at:

Shane Rosanbalm
Rho, Inc.
shane_rosanbalm@rhoworld.com
github.com/rhoinc/sas-viridis