Rainbow Color Map Critiques:
An Overview and Annotated Bibliography

By Steve Eddins, MathWorks

Overview

A rainbow color map is based on the order of colors in the spectrum of visible light—the same colors that appear in a rainbow. Figure 1 shows one particular form of rainbow color map. Since multiple methods exist for computing rainbow color maps, they do not all look identical, but they all feature the same general ordering of colors.

Figure 1. Visible light spectrum.

Data credit: "Spectral and XYZ Color Functions," Jeff Mather, MATLAB Central File Exchange.

Rainbow color maps commonly appear in data visualizations in many different scientific and engineering communities. Technical computing software often provides a rainbow color map as the default choice.

Before Release 2014b, MATLAB® used a rainbow color map as the default for figures. In MATLAB, the rainbow color map is known as the *jet color map* (Figure 2).

Figure 2. The MATLAB jet color map.

Although rainbow color maps remain popular today, they have a number of weaknesses when used for scientific visualization and they have been widely criticized. This paper summarizes the criticisms of the rainbow color map and presents an annotated bibliography of sources. It provides the background for understanding why the MATLAB default color map was changed in R2014b.

The document begins by summarizing the major themes found in literature and online sources about the rainbow color map and about general principles of color in scientific visualization:

- Types of data
- Visualization tasks
- Advantages of rainbow color maps
- Disadvantages of rainbow color maps
- Perceptual color maps
- Experimental studies

- Color-impaired viewers
- Color map construction principles
- Community habits
- Tools

These themes are followed by an annotated bibliography of sources arranged in ascending alphabetical order by the primary author's last name.

Types of Data

The best use of color depends strongly on the type of data, and there are several different major types to consider:

- Nominal, unordered categorical (Example: land area classification – urban, water, vegetation, desert)
- Ordinal, ordered categorical (Example: bond credit ratings – AAA, AA+, AA, AA-, A+, A, A-, BBB+)
- Interval (Example: sea surface temperatures)
- Divergent, a special case of interval data with a value in the middle that is special (Example: elevation, with sea level as the special value)

Rainbow color maps are most often used with interval data, so the remainder of this document focuses on visualizing interval data. Note that some papers and online sources use the term *sequential data* instead. This document uses the term *interval data* to avoid confusion between the terms *sequential* and *ordinal*.

Visualization Tasks

The use of color in two-dimensional data visualization can be assessed in the context of two different types of user tasks:

- Determining a data value at a specific location by looking at a color key. See an example in Figure 3a.
- Assessing surface characteristics, such as peaks, ridges, cusps, saddle points, etc. See an example in Figure 3b.
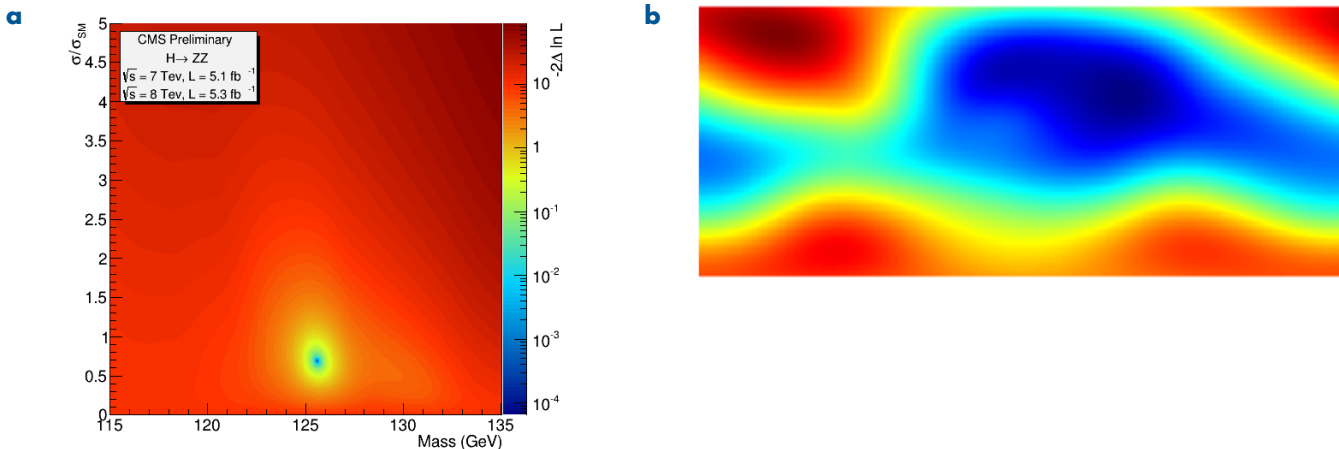

Figure 3. Two different visualization tasks assisted by color: a) Determine the data value at a particular point using the color at that point and the color scale on the right; b) Determine peaks, depressions, ridges, and other features of the Earth's magnetic field intensity.

Image credit (a): Rogowitz, B. & Couet, O., "The Rainbow Color Map." Copyright The Root Team. Used with permission.
Data credit (b): "Magnetic Field Component Grid calculator," National Geophysical Data Center, National Oceanic and Atmospheric Administration.

Advantages of Rainbow Color Maps

Although widely criticized, the rainbow color map (or *jet color map* in MATLAB) does have a few advantages:

- Familiarity: The rainbow color map is widely used in a number of scientific and engineering communities. Members of those communities are accustomed to seeing it, and they expect blue to mean "low" and red to mean "high."
- Attractive display
- Reading data values using a color key: In some parts of the data range, it is easy to match a color in the two-dimensional plot to a color in the key. This characteristic is not consistent across the entire rainbow color map, however. Some portions of the color map, particularly the green and cyan regions, are perceptually indistinct, as shown in Figure 6.

Disadvantages of Rainbow Color Maps

There is a high degree of agreement among the sources about the disadvantages of the rainbow color map:

- It confuses viewers because there is no natural perceptual ordering of the spectral colors (see Figure 4). In addition to causing visual confusion, this lack of natural ordering can slow down tasks because viewers have to refer to the color key more often in order to interpret the visualization.
- It obscures small details in the data (see Figure 6). This happens for two reasons: The green and cyan sections of the rainbow color map are perceptually indistinct, which has the effect of making data in the corresponding ranges appear to be uniform or flat. The human visual system has lower spatial resolution in its response to color variation than to brightness variation.
- It misleads viewers by suggesting data features that are not really there (see Figure 5 and Figure 6). These "phantom" features often take the form of false boundaries. This effect, in combination with the perceptually indistinct color map sections, can falsely segment the data.
- It loses critical information about high and low data values when printed using a gray-scale printer (see Figure 7).
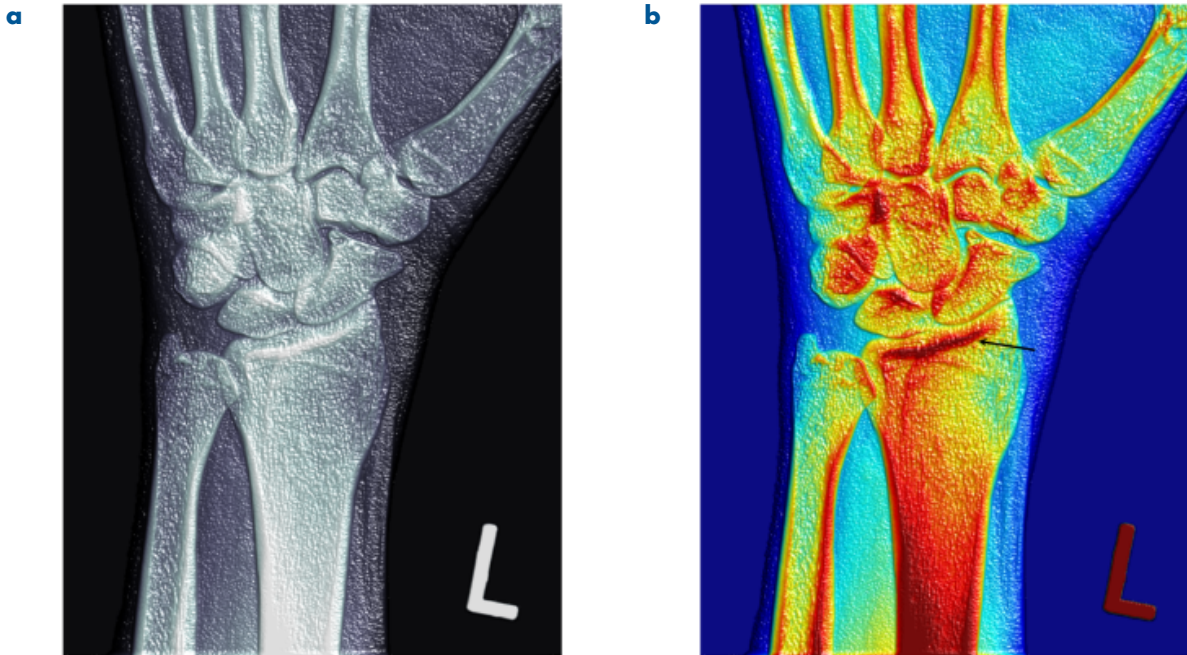

Figure 4. Visual confusion caused by the rainbow color map: a) X-ray displayed using gray-scale color map; b) X-ray displayed using rainbow color map. The dark red suggests a depression in the bone structure that is not really present.

Image credit: Matteo Niccoli, "The Rainbow Is Dead … Long Live the Rainbow!" Copyright 2014 MYCARTA. Used with permission.
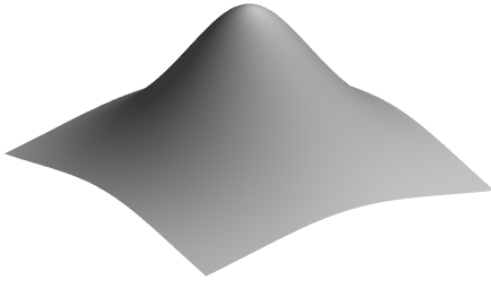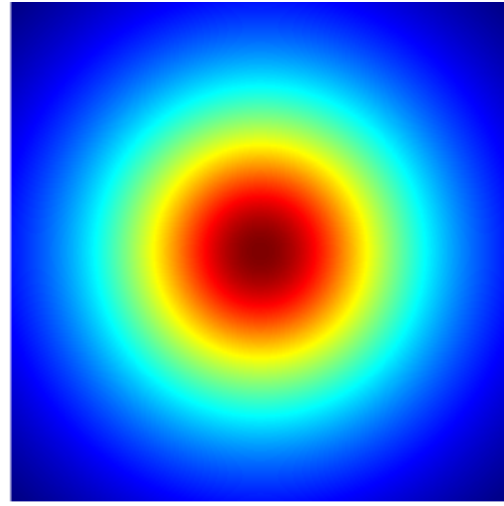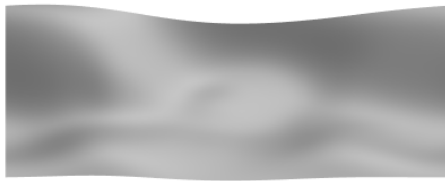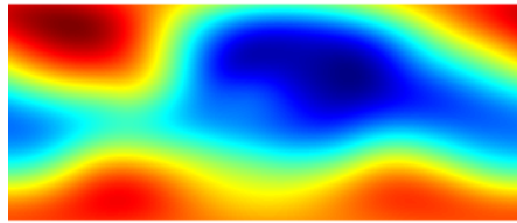
Figure 5. *False bands caused by the rainbow color map for smooth data: a) Synthetic surface with a single peak; b) 2D visualization with rainbow color map; c) Earth's magnetic field intensity; d) 2D visualization with rainbow color map.*

Data credit (c and d): "Magnetic Field Component Grid calculator," National Geophysical Data Center, National Oceanic and Atmospheric Administration.
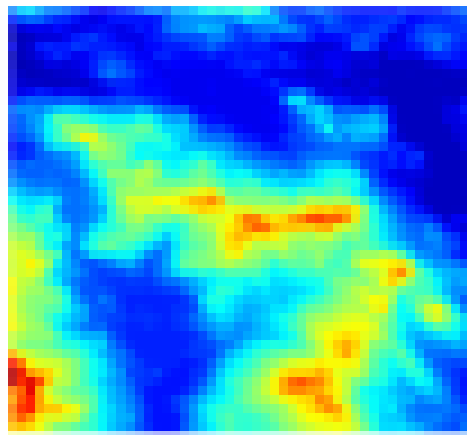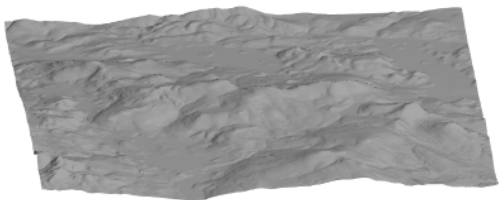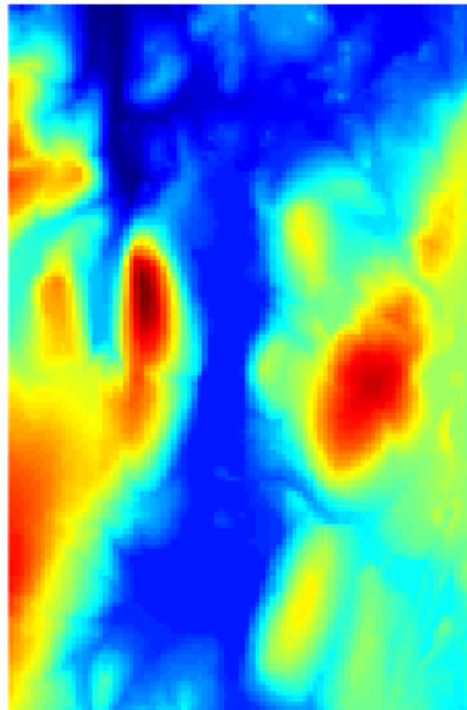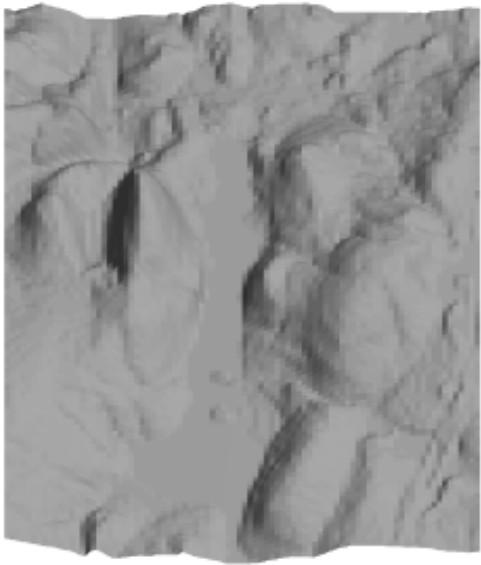
Figure 6. Hidden detail and false segmentation for terrain elevation data at two locations. In the visualizations on the right, the bright yellow lines strongly suggest segmented region boundaries that are actually smooth. The cyan regions hide small details of the terrain.

Data credit: United States Geological Survey.
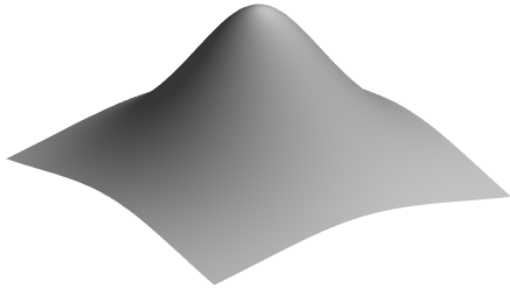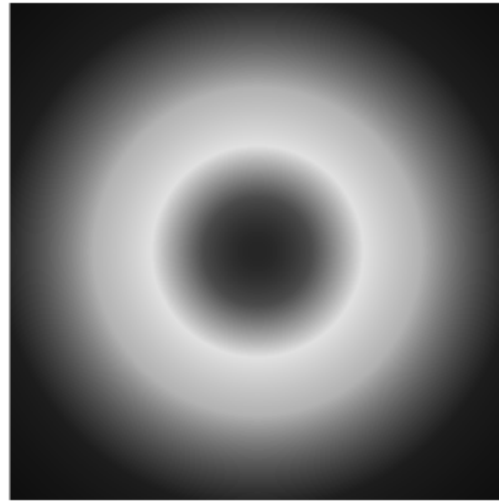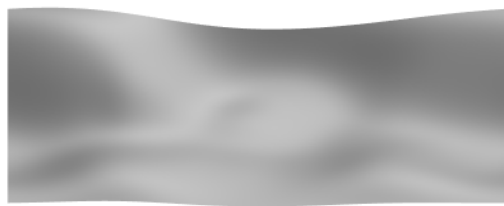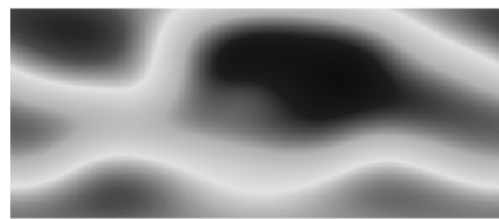
Figure 7. *Gray-scale printing of rainbow color map gives no information about low versus high data values (compare with Figure 5): a) Synthetic surface with a single peak; b) Simulated gray-scale printing of rainbow color map visualization; c) Earth's magnetic field intensity; d) Simulated gray-scale printing of rainbow color map visualization.*

Data credit (c and d): "Magnetic Field Component Grid calculator," National Geophysical Data Center, National Oceanic and Atmospheric Administration.

Perceptual Color Maps

Most of the papers and online sources use the term *perceptual* to describe certain kinds of color maps. A perceptual color map has the property that equal data intervals correspond to the same perceived color difference in all parts of the scale. For data in the range [0,100], for example, the colors corresponding to 20 and 25 appear to be as far apart as the colors corresponding to 50 and 55, and as far apart as the colors corresponding to 90 and 95.

Figure 8 demonstrates that rainbow color maps are decidedly nonuniform perceptually.

Perceptual uniformity is usually achieved with the aid of a color space such as L*a*b* or L*ch.
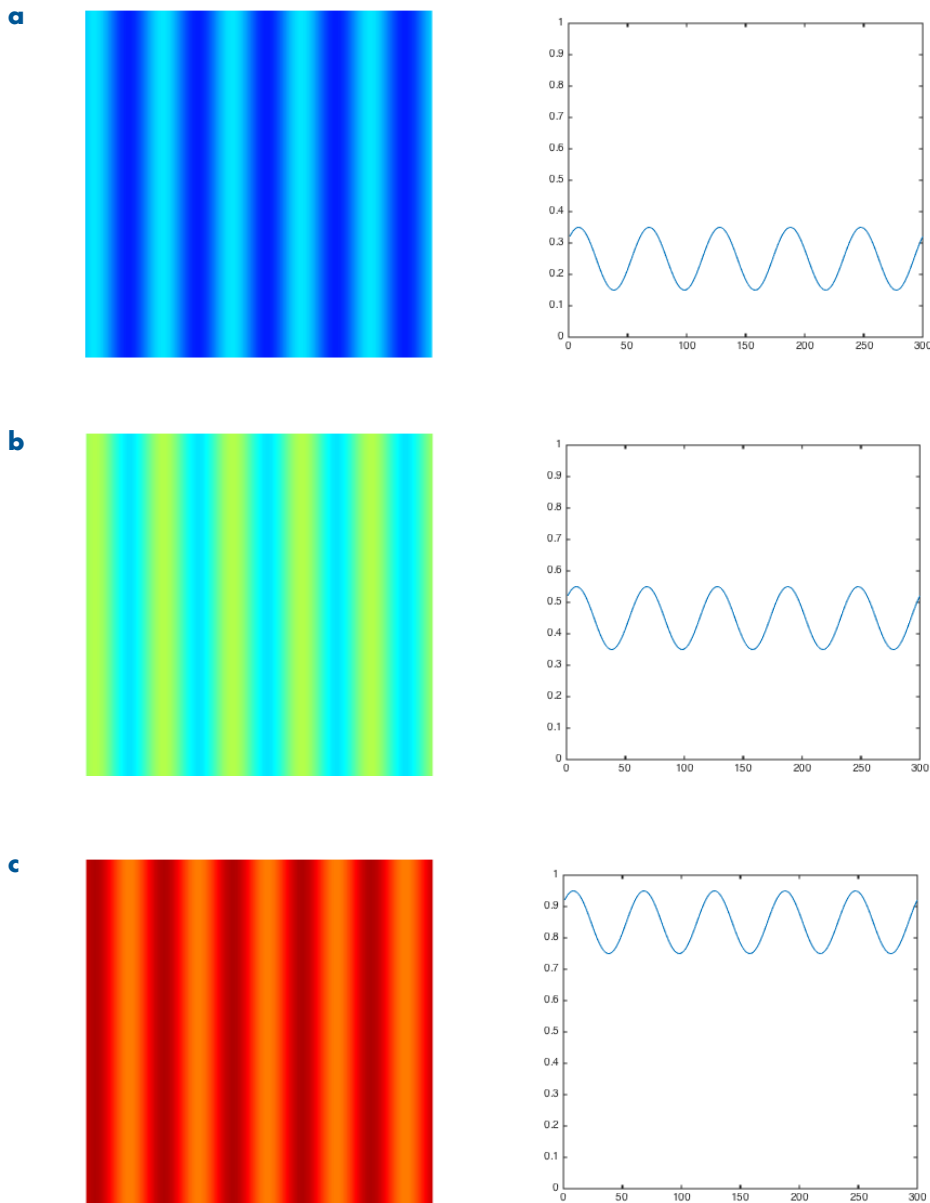
Figure 8. Sinusoidal data at three different offsets visualized using rainbow color map: a) offset = 0.25; b) offset = 0.45; c) offset = 0.85. Despite showing sinusoids containing identical shapes and amplitudes, the three images appear strikingly different. Image "a" has a much higher visual contrast, misleadingly suggesting a higher data variation. Images "b" and "c" have stripes that suggest detail not really present. And, images "a" and "c" incorrectly appear to have opposite phase.

Experimental Studies

A few papers report on the results of quantitative, experimental studies. In these reports, viewers are usually faster and more accurate when using perceptual color maps than when using rainbow color maps. One study went beyond using synthetic data to evaluate the diagnostic performance of medical professionals assessing coronary artery visualizations. Study participants made fewer diagnostic errors when a perceptual color map was used instead of a rainbow color map.

Hue-only or rainbow color maps may be better than purely gray-scale color maps for the task of determining data values from a color key, presumably because of the phenomenon of simultaneous contrast.

Color-Impaired Viewers

Color-impaired viewers can have trouble with the task of determining data values based on the color key. Sources give fairly consistent advice about designing color schemes for color-impaired viewers:

- Avoid spectral schemes such as the rainbow. They have no inherent perceptual ordering and they are susceptible to opponent-order confusion (especially red-green confusion).
- Do not place yellow—the brightest color for both normal and color-impaired viewers—in the middle of a general-purpose color map.
- Use brightness as a perceptual indicator of ordering.

Color Map Construction Principles

Use these guidelines for building effective color maps:

- Construct a perceptual color map by using smooth, equal-step interpolation in a perceptually uniform color space such as L*a*b*.
- Use monotonic lightness (L*) to achieve perceptual ordering and assist color-impaired viewers.
- Do not use lightness variation alone because of the problem of simultaneous contrast. Use hue or saturation variation in addition to lightness variation. (Hue variation can also improve the attractiveness of a color map.)

Community Habits

A community accustomed to the rainbow color map will likely resist change, at least initially. It may become amenable to change, though, if the weakness of the rainbow color map is convincingly demonstrated. Note that a "convincing demonstration" might require more than simply providing literature reports.

Tools

It is still hard to construct excellent color maps. Although tools exist to assist with hue selection and equal-step paths in L*a*b* or L*ch, trial and error is still necessary. It is very important to take the data type and user tasks into consideration. The ideal palette building tool does not exist yet.

Annotated Bibliography

Aisch, G., 2013. "Mastering Multi-hued Color Scales with Chroma.js"
Online. Accessed 23 September 2013.

This blog post by Gregor Aisch about information visualization and data journalism describes the benefits of combining a linearly increasing lightness with multiple color hues. Aisch explains the technical difficulties in creating a multi-hue color map and presents a solution based on Bezier interpolation in the a*-b* plane and on automatic L* lightness correction. He also explains how to use his Javascript library, Chroma.js, to build color maps with this technique (see Figure 9).

Figure 9. *Sample color scale produced with Chroma.js.*

Borkin, et al., 2011. "*Evaluation of Artery Visualizations for Heart Disease Diagnosis*"
IEEE Transactions on Visualization and Computer Graphics, Volume 17.

The authors of this IEEE journal paper investigate both 2D and 3D visualizations of coronary arteries. They present the results of their study in which participants performed various diagnostic tasks using different styles of visualization.

Most visualizations in the study used the rainbow color map, described by the authors as "the standard color map used in the medical literature." One part of the study, however, explored the effectiveness of alternative color maps.

Participants initially preferred the rainbow color map, citing familiarity, more saturated colors, and more pleasing appearance. Remarkably, and in spite of the expressed preference of study participants, the researchers observed that using a "perceptually appropriate color map" resulted in fewer diagnostic mistakes.

At the end of the study, some participants acknowledged that they could see more structure in the data using the alternative color map, and they expressed willingness to use it for data analysis in the future.

Borland and Taylor II, 2007. "Rainbow Color Map (Still) Considered Harmful"
IEEE Computer Graphics and Applications, March/April. pp. 14-17.

In their IEEE journal article, Borland and Taylor are clear and adamant: "The rainbow color map confuses viewers through its lack of perceptual ordering, obscures data through its uncontrolled luminance variation, and actively misleads interpretation through the introduction of non-data-dependent gradients."

Confusion arises because the rainbow color map has no perceptual cues that unambiguously convey data ordering. Most people cannot remember the order of rainbow colors without using a mnemonic such as "Roy G. Biv." I would add that the perceptual cues that do exist in the rainbow sometimes convey exactly the opposite of the true data order. For example, see the false bone structure depression shown in Figure 4, as well as the apparently out-of-phase sinusoids shown in Figure 8.

In Figure 6, we saw how the rainbow color map can obscure small details in the data. In that same figure, we saw how bright stripes falsely suggest segmented regions that, in fact, have no such boundaries in reality.

Borland and Taylor make this last point using several synthetic images, similar in construction to those shown in Figure 5.

The authors discuss characteristics of color maps that make them better suited to certain applications, depending on the data type, such as nominal, ordinal, or interval. They do not recommend a single type of color map as a universally applicable default choice for data visualization toolkits.

Brewer, et al., 2009. "*ColorBrewer 2.0: Color Advice for Cartography*"
Online. Accessed 23 September 2013.

Most recent authors in this field cite ColorBrewer for selecting color schemes for a variety of purposes. This browser-based tool offers several choices for selecting color schemes:

- The number of data classes (a maximum of five to seven classes are recommended for typical chloropleth, or *thematic* maps, but more can be used in certain circumstances)
- The nature of the data (sequential, diverging, or qualitative)
- Special desired color map characteristics (color-blind friendly, color printer friendly, black-and-white photocopy friendly, and laptop LCD display friendly)

Figure 10 shows a screen capture of the ColorBrewer 2.0 interface.
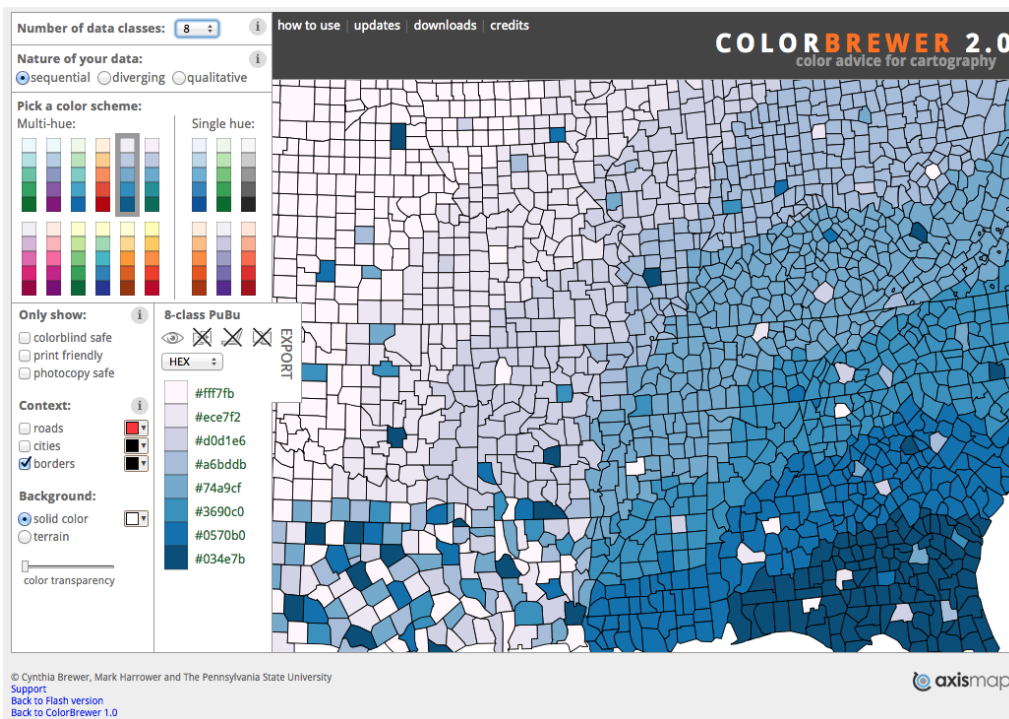
Figure 10. *Screen capture of ColorBrewer 2.0 interface.*

Image credit: Brewer, Cynthia A., 2013, http://www.ColorBrewer2.org. Copyright 2002 Cynthia Brewer, Mark Harrower, and The Pennsylvania State University. Used with permission granted under the Apache License, Version 2.0. http://www.apache.org/licenses/LICENSE-2.0

Kosara, 2013. "*How the Rainbow Color Map Misleads*"
Online. Accessed 16 September 2013.

In his post for the blog "eagereyes: Visualization and Visual Communication," Robert Kosara refers to Borland and Taylor's paper, "Rainbow Color Map (Still) Considered Harmful," noting that their detail discussion relies largely on synthetic data. Kosara points out a real, published map that dramatically illustrates one of the rainbow color map's weaknesses—its tendency to introduce false boundaries.

(I do not have permission to reproduce the figure, which is from the Journal of the American Water Resources Association, so *follow this link* to view it.)

The figure, a plot of the evaporative loss of rain water by county, appears to divide the country sharply down the middle. However, this sharp transition is an illusion caused by the color choices. Significant luminance and hue changes that are not associated with a correspondingly significant data change will cause the visual illusion.

Kosara speculates that the rainbow color map is popular despite its many flaws because it is attractive. He also notes that it is harder to read off individual values from a color scale with a smooth ramp.

For color maps that use more than one or two hues (in order to be attractive), Kosara recommends using either constant or monotonically increasing luminance. A "well-designed color map with increasing luminance can look quite attractive."

Light and Bartlein, 2004. "*The End of the Rainbow? Color Schemes for Improved Data Graphics*"
EOS, Transactions of the American Geophysical Union, 85(40), pp. 385, 391.

Journal paper authors Light and Bartlein do not spare the criticism of color visualizations within their field:

> Flawed graphics [...] beget more flawed graphics as authors emulate published examples. Color has the potential to enhance communication, but design mistakes can result in color figures that are less effective than gray scale displays of the same data.

Light and Bartlein focus most of their attention on the difficulties caused by spectral color maps for color-impaired viewers. They suggest several design principles to improve color schemes and accommodate color vision deficiency.

- Do not use color maps based on the visible light spectrum because it contains no inherent perceptual cues about data magnitude.
- Do not place yellow, which is the brightest of the primary colors for viewers with both normal and color-impaired vision, in the middle of a color map.
- Use brightness, which conveys a perceptual ordering to both normal and color-impaired viewers, as a visual indicator of magnitude.

I would observe that yellow causes many of the problems we have seen with false segmentation and false detail. Refer to Figure 3, Figure 5, and Figure 6.

Niccoli, 2012. "*The Rainbow Is Dead … Long Live the Rainbow*!"
Online. Accessed 18 September 2013.

Matteo Niccoli wrote this seven-part series for his blog "MYCARTA: A blog about Geophysics, Visualization, Image Processing, and Planetary Science."

Part 1 summarizes the criticisms of the rainbow color map in various papers and online sources, most of which are mentioned elsewhere in this bibliography. Niccoli gives one specific criticism that is not widely noted elsewhere: The dark red at the upper end of the color map, for some data, can falsely suggest a depression because of a visual artifact resembling a shadow (see Figure 4).

The author begins to experiment with using the L*a*b* color space to evaluate perceptual properties of color maps.

Niccoli addresses color-blindness in *Part 2*. He constructs an experiment in which seven colors are selected from the rainbow color map and then processed through a filter that simulates how a viewer with deuteranopia might see the colors. It is impossible to determine the order of the processed colors. The author concludes that "trying to fix the rainbow was a hopeless cause."

Part 3 presents two issues with using spectral colors: The variation in perceived brightness (blue is darker than red; yellow is brighter than everything else), and the variation in visual sensitivity to changes in hue (we are most sensitive to changes near yellow). Part 3 suggests possible modifications to rainbow in order to address these issues, but it does not explore these ideas in much detail.

Part 4 and *Part 5* explore the idea of modifying existing color maps by forcing their L* curves to be straight-line ramps. Niccoli starts with the hot color map of MATLAB. He observes that its lightness curve (L*) has two first-derivative discontinuities. Both of these discontinuities are observable as undesirable "edges" in the color map. Part 5 also presents a modified color map.

Part 6 uses a South America DEM to compare four color maps: classic rainbow, a perceptually modified rainbow, the modified color map from Part 5, and a gray-scale color map.

In *Part 7a*, Niccoli introduces his new color map, variously called the perceptual rainbow, cube law rainbow, or cubeYF. In Figure 11, the cube law rainbow is compared with the standard spectrum color map.
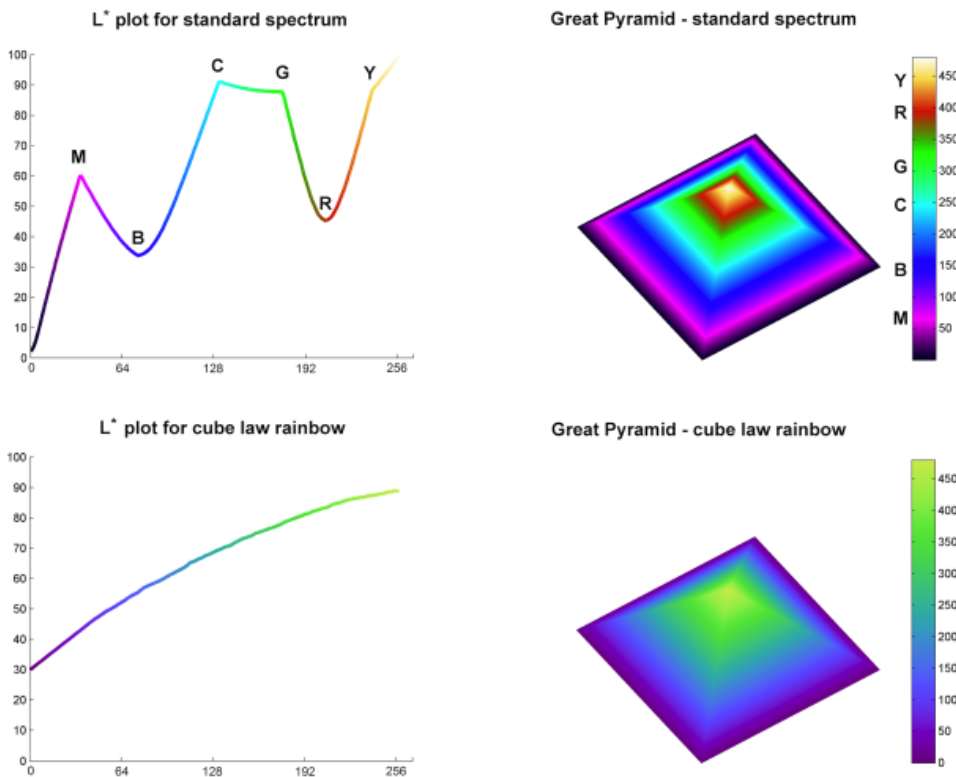

Figure 11. Comparison of standard spectrum color map with cube law rainbow color map on a pyramid shape.

Image credit: Matteo Niccoli, "The Rainbow Is Dead … Long Live the Rainbow!" Copyright 2014 MYCARTA. Used with permission.

Niccoli's use of the term standard spectrum color map is not clear. His standard spectrum color map does not look like the spectrum color map shown in other sources. In particular, the color yellow is out of place at the top of the color map (remember the mnemonic Roy G. Biv.). Also, in constructing the cube law rainbow, Niccoli made L* follow a cube-law curve instead of a straight line. The stated justification is that there is a cube-law relationship between light intensity and perceived brightness (or lightness). However, this cube-law relationship is already incorporated into the formula for L* itself.

Because the cube law rainbow is missing red entirely and has only a bit of yellow (greenish-yellow at the top), it would not be recognizable by most people as a rainbow color map.

Part 7b provides some links of interest:
- *File Exchange contribution* containing the alternative color maps described in this series
- *Colour monitor*, a tool that graphically describes a color palette's "mood"
- The *Global Land One-km Base Elevation Project*, a useful source of data for making sample comparisons

Rogowitz and Kalvin, 2001. The "Which Blair Project": A Quick Visual Method for Evaluating Perceptual Color Maps
IEEE Conference on Visualization, 2001.

In their conference paper with the punny title, Rogowitz and Kalvin propose a cute and thought-provoking idea: If a color map turns something as recognizable as a human face into something barely recognizable, won't it make your data unrecognizable, too?

The authors explore this idea by rendering Tony Blair's face using a large number of color maps. I do not have permission to reproduce that figure, nor do I really want to publish a celebrity likeness here, so I have illustrated the concept using my own picture in Figure 12.

Rogowitz and Kalvin conclude with this simple advice: Apply your color map to a human face. If it renders the face unrecognizable, then it won't do your data any favors, either. Don't use it.

I would like to point out that Rogowitz and Kalvin are not the only ones who could not resist the pun in the title. The journal *Forum: For Promoting 3-19 Comprehensive Education* has published an article entitled "The 'Which Blair' Project: Giddens, the Third Way and Education." I think it is unrelated to color maps.

Figure 12. *Various color maps applied to a face image. The color maps in the bottom row have monotonically increasing lightness, resulting in a natural, recognizable image.*

Rogowitz and Couet. "*The Rainbow Color Map*"
Online. Accessed 17 September 2013.

This online article, intended for the high-energy physics community, is part of the ROOT project, a data processing framework created at CERN.

The article criticizes the rainbow color map for reasons similar to other sources in this bibliography, especially because:

- The lack of natural perceptual cues for data ordering causes visual confusion.
- Detail in the data can be hidden.
- False detail can be introduced, sometimes resulting in artificial segmentation into regions that do not really exist.
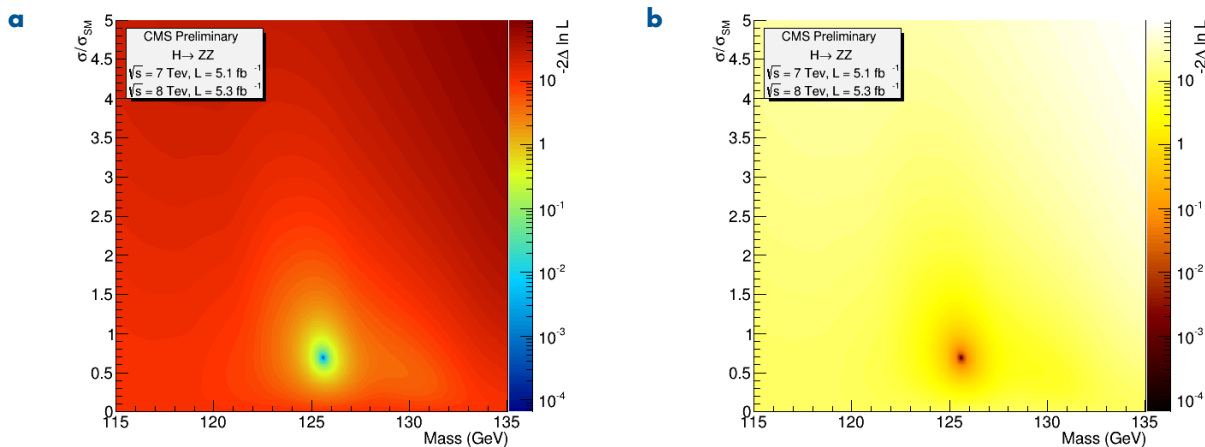

Figure 13. Boson mass at 125 GeV. The data is smooth, but the rainbow color map used in "a" shows banding that does not have any real significance. The dark body radiator color map used in "b" shows a continuous gradation of tones that more accurately reflects the nature of the underlying data.
Image credit: Rogowitz, B. and Couet, O. "The Rainbow Color Map." Copyright The Root Team. Used with permission.

Rogowitz and Treinish, 1998. "Data Visualization: The End of the Rainbow"
IEEE Spectrum, December, pp. 52-59.

In this article from IEEE's flagship magazine, the authors criticize the rainbow color map for potentially leading a data analyst to "incorrect evaluations, conclusions or decisions." They propose principles for evaluating and constructing color maps for use in data visualization. One key principle is that equal steps in the data variable should be perceived as equal steps in the representation. (Earlier I referred to this characteristic as perceptual uniformity.)

Rogowitz and Treinish identify four types of data: nominal, ordinal, interval, and ratio, and they discuss appropriate color map criteria for each. They also identify a special case of interval data when a value in the scale has a special meaning, such as sea level (0 meters) for terrain elevation data.

For constructing improved color maps, the authors use luminance and saturation to convey data variation instead of hue. They note also that the human visual system can process high-frequency luminance variation better than high-frequency color variation. Therefore, they "recommend using a colormap which has a strong luminance variation across the data range."

Simmon, 2013. "*Subtleties of Color*"

Online. Accessed 21 September 2013.

NASA data visualizer and information designer Robert Simmon, sometimes known as "Mr. Blue Marble" for the iconic Earth image he helped to create, wrote a six-part series of articles for the blog *visual.ly* about using color for data visualization.

The author notes in *Part 1* that several factors complicate the use of color for data visualization, including:

- The human visual perception system is very complex.
- The type of data (interval, ordinal, nominal, etc.) influences the choice of color scheme.
- Many viewers have impaired color vision.

Simmon goes on to describe basic aspects of color theory and recommends the use of a perceptual color space, such as CIE L*ch.

Part 2, The "Perfect" Palette lists research papers in the 1980s and 1990s that explored how to use and how not to use color in data visualization. (Some of these papers are covered elsewhere in this bibliography.) Much of the research advocates perceptual uniformity. That is, "a color scale should vary consistently across the entire range of values, so that each step is [perceptually] equivalent, regardless of its position on the scale." A consistent relationship "preserves the form of the data." On the other hand, "palettes with abrupt or uneven shifts can exaggerate contrast in some areas, and hide it [in] others."

This part introduces the rainbow color map and discusses its characteristics.

Simmon comments that the simple gray-scale color map, which has some good characteristics, suffers from the phenomenon of simultaneous contrast. This optical illusion (see Figure 14) can make it difficult to read specific numeric values from a color legend.

Figure 14. Simultaneous contrast effect in a gray-scale color map. Although all appear to be different, each circle is the same shade of gray.

The recommended way to overcome the simultaneous contrast effect is to combine lightness, hue, and saturation changes.

Part 3, Different Data, Different Colors describes some of the issues associated with designing color maps for divergent data and for qualitative (categorical) data.

With divergent data, it is important to clearly distinguish between data above and below a certain critical value, such as sea level (0 meters) in elevation data. Color maps for divergent data can be formed by merging two sequential color maps "with equal variation in lightness and saturation." The central shade separating the two sequential color maps should be "white or light gray."

The author goes on to describe some of the challenges associated with qualitative (categorical) data. "Due to the limits of perception, especially simultaneous contrast, the maximum number of categories that can be displayed is about 12 (practically speaking, probably fewer)." For displaying a larger number of categories, a grouping of categories is recommended.

Simmon examines the more subtle aspects of using color for data visualization in *Part 4, Connecting Color to Meaning*, including:

- Intuitive color choices ("matches the audience's preconceptions and cultural associations")
- Layering two or more data sets (Here the author again criticizes the rainbow color map, noting that layering is "pretty much impossible if you've already used all the colors of the rainbow to display a single dataset.")
- Complementary data sets
- Non-diverging breakpoints
- Separating data from non-data

This part contains some particularly beautiful and effective visualization examples.

The author recommends palette building tools in *Part 5, Tools and Techniques*. These are especially noteworthy:

- *ColorBrewer*
- *NASA Ames Color Tool*
- Chroma.js

Simmon points out weaknesses in all of these tools and then gives an extensive list of desired characteristics for his "ideal palette building tool."

In *Part 6, References and Resources for Visualization Professionals*, Simmon's top three essential references include:

- *Information Visualization: Perception for Design*, by Colin Ware
- *Envisioning Information*, by Edward Tufte (specifically, the chapter on color and information)
- The supplementary information in Cynthia Brewer's *ColorBrewer* tool

Additional resources given include artists, cartographers, designers, scientific papers, alternative color map design approaches, and online information and blogs by visualization practitioners.

Spence, et al., 1999. "*Using Color to Code Quantity in Spatial Displays*"
Journal of Experimental Psychology: Applied, 5(4), pp. 393-412.

In this experimental study, the authors assessed the speed and accuracy of study participants in determining data value (quantity) and identifying clusters. Color maps that were perceptually linear and varied in "only brightness" or "brightness + hue + saturation" resulted in faster, more accurate judgments than a hue-only color map. Hue does confer an advantage if the task involves segregation or classification.
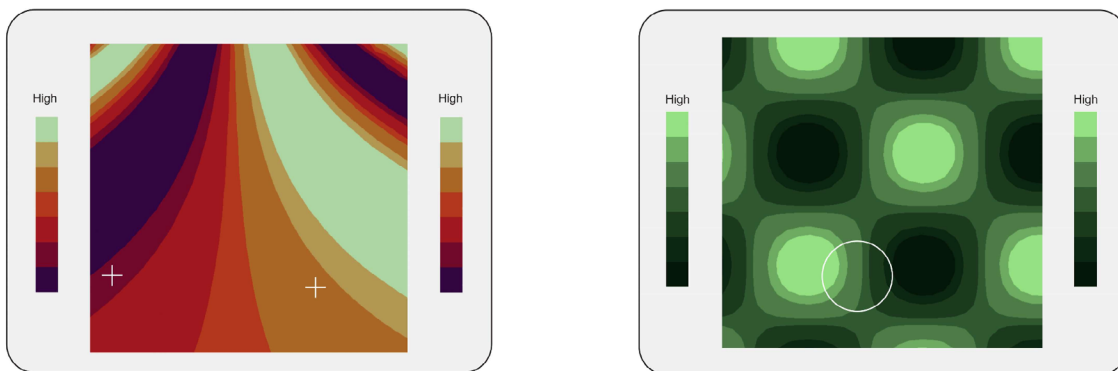

Figure 15. Sample experimental stimuli. On the left, the participant is asked to determine which cross has the higher data value. On the right, the participant is asked to move the circle to a higher location. Speed and accuracy are assessed.
Image credit: Spence, I., Kutlesa, N. & Rose, D. L., 1999. "Using Color to Code Quantity in Spatial Displays." Journal of Experimental Psychology: Applied, 5(4), pp. 393-412. Used with permission.

Van Slembrouck, 2012. "*There's Something About Yellow*"
Online. Accessed 17 September 2013.

In this post written for the blog *visual.ly*, Van Slembrouck explains the special characteristics of yellow. I have mentioned yellow frequently in this document because of its tendency to cause false segmentation or banding in visualizations. Van Slembrouck tells us why: Because yellow strongly excites both types of color receptors in our eyes, we see yellow as the brightest color in the spectrum.

The author also notes that yellow is considered to be "safe" for use with color-impaired viewers. He generally recommends using color schemes that incorporate purple/blue and yellow/orange for such viewers.

Ware, 1988. "*Color Sequences for Univariate Maps: Theory, Experiments, and Principles*"
IEEE Computer Graphics and Applications, pp. 41-49.

In this IEEE journal article, Ware systematically studies the effectiveness of several different color maps for two different tasks: looking up the data value at a particular location based on a color key, and evaluating the form or shape of the data. The paper uses the term *metric* instead of *value* to avoid confusion with the different meaning of value in a color science context. Several different characteristic shapes are used to evaluate the perception of form: gradient, ridge, convexity or concavity, saddle, and cusp.

Ware is one of the few authors who identifies an advantage of the spectrum (or rainbow) color map: It can sometimes be more effective for reading data values using a color legend. A gray-scale color map is less effective for this task because of the simultaneous contrast phenomenon, as we saw in Figure 14.

On the other hand, a color map that is monotonically increasing in luminance is more effective for accurate perception of shape or form.

For success at both tasks—reading data values and evaluating form—Ware recommends a hybrid color map that "increases monotonically in luminance, while cycling through a range of hues. The hues provide accurate readings from a key, while the luminance conveys the form of the surface."

Conclusion

Choosing an effective color map to visualize data presents many challenges. Factors to consider include the type of data, technical accuracy, artistic concerns, and human visual perception. Selecting a general-purpose color map that works well in all situations is especially difficult.

That said, MATLAB provides a default color map when you do not specify one. Before R2014b, the default was a *jet color map*, which is a type of rainbow color map.

Although the rainbow color map does have a few advantages, and some scientific and engineering communities customarily use it, it has some significant drawbacks for general-purpose data visualization. It confuses the visual interpretation of data, hides some detail, and falsely suggests detail where none is truly present.

The attributed references explore and explain these drawbacks in detail. Collectively they suggest certain characteristics, such as increasing lightness and perceptual uniformity, which an improved color map might possess. Influenced by this body of research, MathWorks designed a new default color map for R2014b that incorporates these characteristics.

Learn More

To learn more about the new MATLAB color map, follow the articles posted in the *color map category* of the blog "*Steve on Image Processing*." For examples showing how to change the color map, or for a list of color maps provided with MATLAB, see the documentation for the `colormap` *function*.

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