

Redesigning the MAGE palette

09/27/2023

Introduction

MAGE uses a palette of 25 named colors for rendering graphics objects. Each of the 25 is actually a set of five closely related shades that are used to impart a sense of depth to the image, with the front of the object being rendered in a stronger tone and the rear fading into the background. Also, the graphics may be displayed with either a solid white or a solid black background, so two different complete palettes are required.

The result is that MAGE uses 250 distinct colors to render its graphics. Previously, each of these was designed by eye and specified individually in the red-green-blue (RGB) colorspace. The palette for use with a black background was very good, but the one for a white background was somewhat lacking. This document describes recent efforts to improve both palettes, but especially the white-background one.

The following criteria were used in designing the new palette scheme, and are listed roughly in order of importance:

1. The colors should be pleasant to look at for an extended period of time on either the black or the white background.
2. The shades of each color should convey depth as well as possible.
3. It should be possible to organize the named colors into progressions and families based on both hue and lightness/darkness.
4. The colors should be maximally distinguishable from one another.
5. The colors should retain these properties on a variety of different monitors with differing configurations, as well as on the printed page.
6. The color definitions should be simple and intuitive, with a minimal number of parameters to be specified.

The HSV scheme

As it turns out, the simplified scheme for defining colors was key to achieving the other properties, and so will be described first. The new palette was not defined in RGB colorspace, but rather in hue-saturation-value (HSV) colorspace¹. *Hue* is given as an angle on the color wheel, from 0 to 360 degrees, where 0 = 360 = pure red. *Saturation* is given as a percentage between 0 (a shade of gray, no hue) and 100 (maximum contribution from hue). *Value* indicates the brightness or luminosity, and is given as a percentage with 0 = black and 100 = white.

Each named color was previously defined with 30 parameters: red, green, and blue values for five shades on two backgrounds. In the revised scheme, each color with is specified with five. The same hue is used on both backgrounds, but saturation and value are specified independently. These numbers define the first or frontmost color in the progression of shades, and the others are calculated from it.

The formulas used for deriving the other shades were based on careful observation of the original, hand-built palettes. On a black background, hue and saturation were approximately constant for a single named color, but value (*i.e.*, brightness) decreased as the shades receded into the distance. On a white background, hue held steady, but saturation decreased *and* value increased as the shades receded into the distance.

Both cases can be regarded as an interpolation from the frontmost starting shade toward the background color. Any color with a value of 0 is black, regardless of hue or saturation, which explains why only value needs to be manipulated to accomplish a fade towards black. White, however, requires that value be 100 *and* that saturation be 0; thus, both parameters must be varied to get believable fading.

Interpolation is done linearly, with constant-size steps between the shades. Since this approach yields a very good palette, no more complicated scheme was sought.

Color families

The MAGE named colors are organized in two “directions”, as shown in Fig. 1 (TODO). The vertical axis shows progression in hue, with a rainbow of colors. The horizontal axis shows progressions in lightness/darkness, where sets of two or three colors look like they belong together, but differ in saturation and/or value. Note that some colors serve in two different places in the chart.

On a black background, the light-to-dark progressions go from the pastels to the semi-saturated colors to the saturated colors. On a white background, however, they go from the semi-saturated colors to the saturated colors to the pastels (which, despite the name, are quite dark).

¹ *Brightness* is sometimes used as a synonym for *value*, and so this colorspace is also called HSB.

Adjusting the color definitions

All of the initial HSV definitions were based on the original MAGE palette. However, some adjustments were made.

Hue spacing

There are 13 colors that form the primary progression in hue: red, orange, gold, yellow, lime, green, sea, cyan, sky, blue, purple, magenta, and hotpink. There are six “anchor” colors whose hues correspond to the standard RGB definitions: red (hue = 0), yellow (60), green (120), cyan (180), blue (240), and magenta (300). The other colors are spaced evenly between their flanking anchors, with a few exceptions. Lime is closer to yellow than to green, because colors near green are hard to distinguish from one another on many monitors. Purple is slightly closer to magenta than to blue, again to improve visual separation. Hotpink is also slightly closer to red than to magenta, for the same reason.

Most of the light-to-dark progressions (*e.g.* pinktint-pink-red, bluetint-blue) show some variation in hue; in fact, only yellow and yellowtint share exactly the same hue. This can be attributed to the fact that there are fewer colors in the hue progressions for the semi-saturated and pastel colors, and the hues vary to maximize the distinctiveness of each color. For instance, red and orange are only 20 degrees apart in hue, but pink and peach are 35 degrees apart.

Value and saturation (black background)

For the most part, all colors on the black background start at 100% value. The exceptions are some of the neutrals (gray, brown) and colors near cyan (cyan, sky). For some reason, cyan appears unusually luminous on most computer monitors, and so it starts off at a reduced value to compensate.

Levels of saturation are used to distinguish different groups of colors, but with each group there are a few trends worth noting. Green, blue and purple all benefit from a reduction in saturation relative to their peers; at full saturation on a black background, these colors are jarring and almost seem to vibrate. Colors near yellow tolerate the least desaturation; dark and desaturated yellows and oranges quickly become muddy and then turn into brown.

Value and saturation (white background)

Full, 100% value is a disaster against a white background. Those colors are too luminous to be easily separated from the background and strain the eyes. No color except blue has a value above 90%; blue appears so dark in contrast to white that it can tolerate the higher value. (Even for blue, a slightly lower value would be preferable, but the higher one helps with separation from bluetint, which is not much darker but already so dark as to be difficult to distinguish from black.) Both green and greentint have lower values than any of the other

members in their hue progressions. This may be due to the fact that human eyes are more sensitive to green wavelengths than to red or blue.

Most colors on a white background are fully saturated (except for the neutrals). Again, cyan's high luminosity recommends deemphasizing it, and green and blue also benefit from some reduction in saturation.