Abstract:

This paper proposes a structured way to use color to enhance a visualization. Focus is on the visualization of graphs/maps, containing one and two-dimensional data. There is also discussion of how to attempt to optimize a color scheme so that it can still be used effectively by colorblind individuals.

Summary:

Color has three dimensions:

- **Hue** - the actual "color" (i.e. red, green, blue, etc.)

- **Lightness** – a relative measure of how “bright” a color appears to be in a given context

- **Saturation** - vividness of a color, like different shades

Proposed Guidance framework:

Three basic schemes of one-variable data are identified, sequential, such as a series of scalar values in a single dimension, binary/qualitative, which pertains to differing categories of data, and diverging, which is concerned with looking at trends along a single dimension (i.e. was there an increase over a given time period, or was there a decrease).

For sequential data, use varying lightness to represent monotonic sequences (possibly varying hue as necessary if the data contains multiple such sequences and you wish to make comparisons with them).

Examples:

- high income = light colors, low income = dark
- well educated, high income = light red, poorly educated, low income = dark blue

For binary/qualitative data, use varying hues to distinguish between distinct categories. Choose hues carefully to balance contrast and
visibility with the chosen background color. Try to keep things even between categories if all are of the same importance.

Example:

Using different colors to denote different countries on a map

For diverging data, vary hue and lightness (i.e. a spectral scheme) when looking at trends in a single dimension.

Example:

dark blue = strong decrease, white/light yellow = no change, dark red = string increase

Some two-variable schemes are also created by combining the above schemes. The useful schemes identified are sequential-sequential, sequential-qualitative, binary-qualitative, binary-diverging, sequential-diverging, and diverging-diverging. See http://www.personal.psu.edu/cab38/ColorSch/SchHome.html for more information.

Saturation may also be used much the same way lightness is used, although people are not as good at comparing variance in saturation, especially among different hues, so saturation should mostly be used to add emphasis when necessary.

Differing hues can also be used to represent ordered (i.e. “sequential”) data, although care must be used in selecting the hues, and lightness should still be used logically in conjunction.

Other topics mentioned:

Colorblindness can cause difficulties and should be taken into account. Recommended color schemes are red-blue, red-purple, orange-blue, orange-purple, brown-blue, brown-purple, yellow-blue, yellow-purple, yellow-gray, and blue-gray.

Spectral schemes can pose problems, but colorblind people can still perceive a well-designed yellow-orange-red scheme as a brightness sequence and thus still effectively use it.
Context is important as well. For example, background colors can affect perceived brightness, a small object size can make hue harder to determine, and so on. Care must be taken to make sure the final visualization looks acceptable (i.e. do not just look at the key and assume everything is fine).

There is also discussion of the CMYK color mixing scheme used by printers, but I cannot fathom why, except possibly as a comparison to perceptual mixing schemes.

Perceptual color mixing schemes are scaled so the perceived differences are more-or-less in sync with the scalar values used to specify the color. CMYK is not a perceptual scheme.

**Issues Raised:**

The paper, while not groundbreaking, does propose what seems to be a sound methodology for using color to help represent one and two dimensional data, and optimizing color usage (and other aspects) in visualizations is a current and important area of discussion.

The discussion on how to optimize things for colorblind individuals is an important aspect raised by the paper, as I do not think that there currently is much focus or discussion on how to design a visualization such that it is both easy to use and good looking in general and also still accessible to colorblind people.