Color Contrast and Differentiation in Interactive Cartography A. J. Johnson, N. M. Estes, School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, ajohnson@ser.asu.edu

Introduction: The Lunar Reconnaissance Orbiter Camera (LROC) Science Operations Center (SOC) deploys the Lunaserv Web Map Service (WMS) software in support of both internal and external data visualization needs [1]. The most common use case for Lunaserv is rendering multiple vector layers over a basemap. The extreme color range and variation encountered in Lunaserv basemaps can be seen by comparing the WAC global (Fig. 1) [2] and the WAC GLD100 color shaded relief (Fig. 2) [3]. The WMS client is free to overlay a basemap with any combination of available layers, in any order. This creates a challenge: rendering several easily visible layers (often only a pixel wide) over a background that may contain any color, and may change rapidly as the user pans and zooms. Addressing this challenge requires a set of colors that contrast with almost any background, and every other color in the set.

Approaches for Color Categorization and Differentiation: There are several color catalogs that help to describe colors in a consistent and reproducible language. The Inter-Society Color Council/National Bureau of Standards (ISCC-NBS) color catalog [4, 5] and the standard list of "web safe" colors [6] served as starting points for research. Existing sources of color coding and differentiation were investigated, including filing systems (Fig. 3), transit system maps (Fig. 4), Kenneth Kelly's twenty-two contrasting colors [7], USGS recommendations [8], and the color alphabet [9]. Different methods of generating sets of contrasting colors algorithmically were also researched. Most of the methods found involve operating in hue-saturation-lightness (HSL) color space and applying a fixed or slightly varying number to saturation and lightness, while dividing the hue spectrum into even intervals [10]. The resulting color set must be converted back into the red-green-blue-alpha (RGBA) color space for the WMS software. To more directly meet the needs of Lunaserv, an algorithm was devised to generate colors with maximum contrast based in the RGB color space [11]. This method divided the RGB space into intervals with values mathematically most different from one another, with the hypothesis that colors that are most mathematically different are also most visually distinct.

Selection of Color Set: Requirements for the color set included: 1) maximum visual contrast in any layer configuration with any basemap, 2) sufficient in quantity to render eighteen distinct layers, and 3) meeting the needs of color-blind users as much as possible. Colors from each source were overlaid on several basemaps and tested with human viewers for contrast against the base layer.

Results: "Web safe" colors proved irrelevant, as the list was designed to accommodate 8-bit color screens, which were superseded in the early 1990s [12].

The color algorithm successfully identified a list of maximally mathematically different colors; however, they were not the most visually distinct, as seen when comparing those colors rendered over a basemap (Figs. 5, 6) with Kelly's colors rendered over a basemap (Figs. 7, 8). The insufficiency of mathematical difference highlights the complicated nature of the problem, namely, that complex optical factors involved in human vision.

In the end, we found that Kenneth Kelly's list of 22 contrasting colors [7] from the ISCC-NBS color catalog [4] most successfully matched our priorities and constraints. The first nine colors in Kelley's list were carefully chosen to contrast even for people who are rd-green colorblind (based on the earlier work of Deane Judd [13]), and there was minimal overlap between this color set and the dominant colors of the various lunar basemaps in Lunaserv. Where overlap existed, the colors were removed or de-prioritized.

Conclusions: Selection of contrasting colors is a much more complicated problem than *prima facie* appearance, as human optics introduce a complex variable into the process. Previous research into the topic of color selection continues to be highly useful, even in applications far more complex than were available at the time of the research.

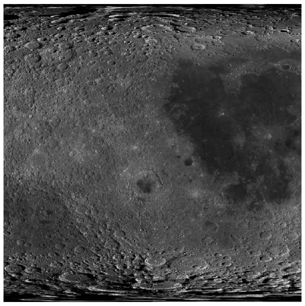

Figure 2: LROC WAC Global Mosaic [2].

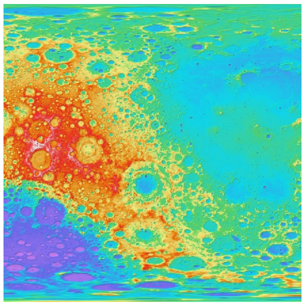

Figure 1: LROC WAC GLD 100 Color Shaded Relief [3].

Figure 3: Example of color coded filing system.

Figure 4: Example of color coding on a transit map. © Maximilian Dörrbecker under Creative Commons Attribution-Share Alike 2.5 license.

Anecdotally, some colors from the final set, when overlaid as vector layers on basemaps with highly similar colors, were still visually discernible, because the geometric nature of the vector layer itself provided sufficient textural contrast to clearly identify the layer. The effect of textural contrast on visual contrast may represent an important future area of research.

References

[1] Estes, N.M.,0 et. al., (2013) Lunaserv Web Map Service: History, Implementation Details, Development, and Uses, http://adsabs.harvard.edu/abs/2013LPICo1719.2609E.
[2] Speyerer, E. J., et. al. (2011) Lunar Reconnaissance Orbiter Camera global morphological map of the Moon, Lunar Planet. Sci. XLII, Abstract 2387.
[3] Scholten, F., et. al. (2012) GLD100: The near-global lunar 100 m raster DTM from LROC WAC stereo image data, J. Geophys. Res., 117, E00H17, doi:10.1029/2011JE003926.
[4] The ISCC-NBS method of designating colors and a dictionary of color names. National Bureau of Standards Circular 553. U. S. Government Printing Office, Washington, 1955. 158 pp.
[5] Kelly, Kenneth L. (1965) A Universal Color Language; Color Engineering 3:16.
[6] HTML Colors http://www.w3schools.com/html/html_colors.asp
[7] Kelly, Kenneth L. (1965) Twenty-Two Colors of Maximum Contrast; Color Engineering, 3:26-27.
[8] U.S.G.S. (2005) Selection of Colors and Patterns for Geologic Maps of the U.S. Geological Survey, http://pubs.usgs.gov/tm/2005/11B01/05tm11b01.html
[9]Green-Armytage, Paul (2010) A Colour Alphabet and the Limits of Colour Coding; Journal of the International Colour Association, 5:2-5.
[10] Campadelli, Paola, et. al. (1999) An Algorithm for the Selection of High Contrast Color Sets; Color Research and Application, 24(2):132-138.
[11] Johnson, Alexander, (2015) ruby_color_picker, https://github.com/axle07/ruby_color_picker
[12] Robbins, Jennifer N. (2006) Web Design in a Nutshell, 3rd Edition, 522.
[13] Judd, Deane B.;Color Perceptions of Deuteranopic and Protanopic Observers (1948) J. Research; NBS 41, 247.

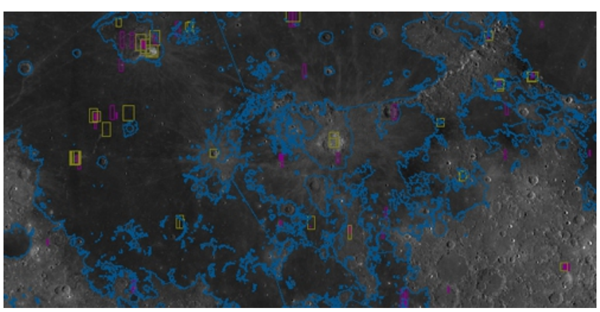

Figure 5: WAC Global Mosaic [2] with three RDR vector layers showing the algorithmic color selection.

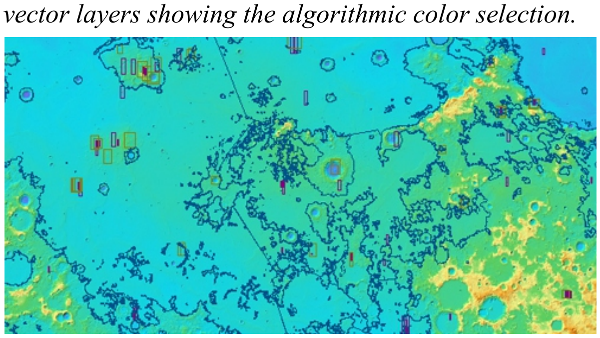

Figure 6: WAC Global Mosaic [2] with three RDR vector layers showing the algorithmic color selection.

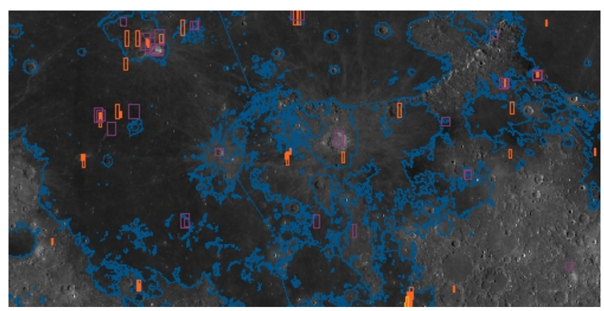

Figure 7: WAC Global Mosaic [2] with three RDR vector layers showing the final color selection.

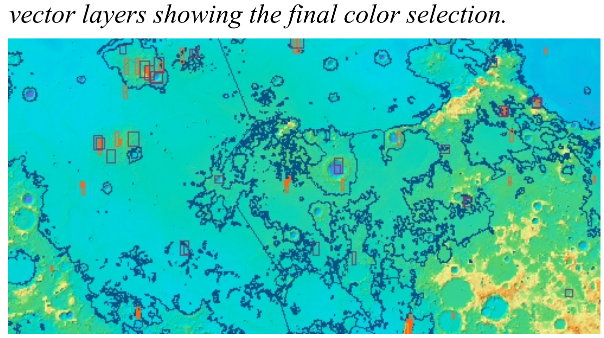

Figure 8: WAC GLD 100 color Shaded Relief [3] with three RDR vector layers showing the final color selection.