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

Introduction: The Lunar Reconnaissance Orbiter Camera (LROC) Science Operations Center (SOC) operates a server running Lunaserv Web Map Service (WMS) software in support of both internal and external data visualization needs [1]. A common use case for Lunaserv is rendering multiple vector layers over a base map. The base map can contain any number or variety of colors, and may be overlaid with several vector layers. The extreme color range and variation encountered in Lunaserv base maps can be seen by comparing the WAC global base map (Fig. 1) [2] and the WAC GLD100 color shaded relief base map (Fig. 2) [3]. The WMS client is free to select any combination of layers, in any order, with any base map in any projection. Additionally, the colors displayed by the base map can change rapidly as the user pans and zooms. This creates the challenge of finding a set of colors that contrast with almost any background and each other.

General 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 [8, 9] and the standard list of web safe colors [4] served as starting points for this work. Existing sources of color coding and differentiation, including filing systems (Fig. 3), transit system maps (Fig. 4), Kenneth Kelly's twenty-two contrasting colors [6], and the color alphabet [7] were examined for efficac in choosing contrasting color values. Different methods of generating sets of contrasting colors algorithmically were also examined. Most of the methods found involved operating in HSL color space and applying a fixed or slightly varying number to saturation and lightness, while dividing the hue spectrum into even intervals [5]. The resulting color set does not consider the background for the color application, and must also be converted back into the RGBA color space for the WMS software. Alex Johnson devised a method of generating colors with maximum contrast for WMS vector layers, based in the RGB color space. His method divides the RGB space into intervals that are mathematically farthest from one another, and avoiding dominant colors in the available base maps.

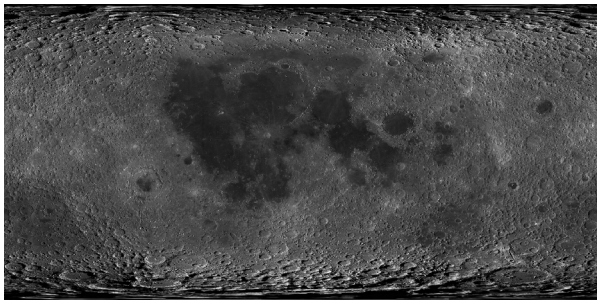

Figure 1: LROC WAC Global Mosaic [2]

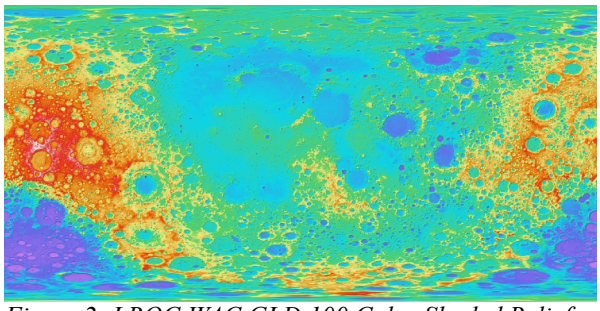

Figure 2: LROC WAC GLD 100 Color Shaded Relief [3]

Method for Selection of Color Set: The requirements for the layers in Lunaserv were to retain maximum visual contrast in any layer configuration with any base map, to have as many colors in reserve as possible to allow for adding more vector layers in the future, and accommodating color-blind users as much as possible. While Johnson's color algorithm successfully identified a list of maximally mathematically distinct colors, they were not the most visually distinct. This highlights the complex nature of the problem: simply selecting distinct colors is not sufficient, as there are complex optical factors to consider.

In the end, we found that Kenneth Kelly's list of 22 contrasting colors [6] from the ISCC-NBS color catalog [8] most successfully matched our priorities and constraints; the first nine colors in the list were carefully chosen to contrast even for people who are red-green colorblind based on the earlier work of Deane Judd [10], and there was minimal overlap between this color set and the dominant colors of the various lunar base maps the LROC SOC makes

Figure 3: Example of color coded filing system. © Alex Gorzen under Creative Commons Attribution-Share Alike 2.0 license.

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

available in Lunaserv. Kelly's colors were then tailored for use with Lunaserv, removing or de-prioritizing the few colors that were highly similar to the dominant colors of one or more base maps. Some colors appearing similar to base maps did not need to be addressed, as the geometric nature of the vector layer itself provided sufficient textural contrast to clearly identify the layer.

Conclusions: While initially appearing to be a trivial problem, selection of a contrasting color set is much more complicated in practice. Prior work by Kelly and others involving human perception of color and the effects of colorblindness is invaluable, even in new applications that weren't conceived of in that time. By contrast, the list of web safe colors for maximum cross-device compatibility is much less important with the current generation of display technology [4]. The difference in color spaces is also less problematic for this use case since the subtle differences between them when converting colors is less noticeable when the goal is maximum perceptual contrast between colors.

References

[1] Estes, N.M.; 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] HTML Colors http://www.w3schools.com/html/html_colors.asp

[5] Campadelli, Paola, et. al.; An Algorithm for the Selection of High Contrast Color Sets; Color Research and Application, 24(2):132-138

[6] Kelly, Kenneth L.; Twenty-Two Colors of Maximum Contrast; Color Engineering, 3:26-27, 1965.

[7] Green-Armytage, Paul; A Colour Alphabet and the Limits of Colour Coding; Journal of the International Colour Association; volume 5.

[8] 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. v + 158 pp.

[9] Kelly, Kenneth L.; A Universal Color Language; Color Engineering 3:16, 1965.

[10] Judd, Deane B.;Color Perceptions of Deuranopic and Protanopic Observers; J. Research; NBS 41, 247 (1948).

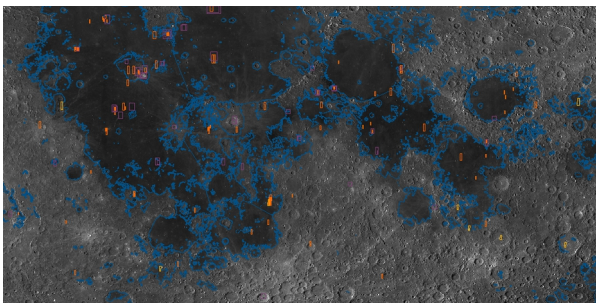

Figure 5: WAC Global Mosaic [2] with four RDR vector layers showing the resulting color selection.

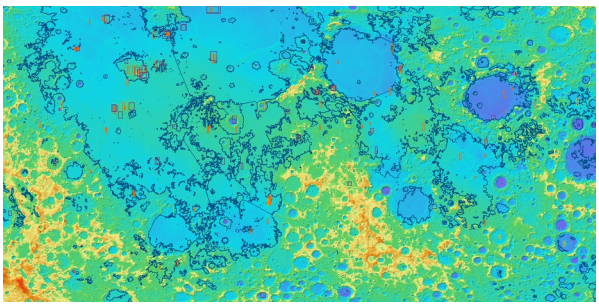

Figure 6: WAC GLD 100 color Shaded Relief [3] with four RDR vector layers showing the resulting color selection.