Mapping Matters

By Qassim A. Abdullah, Ph.D., PLS, CP**

Your Questions Answered
The layman's perspective on technical theory and practical applications of mapping and GIS

Question: I'm looking for a simple, user-friendly term to better describe (for the non-techy) the process of "pan sharpening."

Anonymous, Richmond, VA, USA

Dr. Abdullah: First, I would like to discuss the two main characteristics that describe any digital raster image: spatial and spectral resolutions.

Spatial resolution is a measure of the smallest distinguishable object in an image; however, the casual meaning for spatial resolution, which evolved within the GIS and remote-sensing community, is associated with the distance on the ground that is covered by the smallest picture element, or a single pixel. Right or wrong, the most common terms used to describe the spatial resolution of an image are the ground sampling distance (GSD) and the ground resolution. There is a good reason why the community developed such an understanding for the spatial resolution. Measuring the distance that a pixel covers on the ground and relating it to the physical size of the sensor element, or the Charge Coupled Device (CCD), brings home the topics of map and photo scale, which were lost when we moved to the digital world. Users are accustomed to relating a feature in a photo to its physical dimensions on the ground, and GSD does just that for digital imaging.

Spectral resolution is a measure of the spectral bandwidth used in a certain image. This measure usually starts with the sensor capabilities, as we have panchromatic sensors that are sensitive only to the panchromatic band or the portion of the electromagnetic spectrum covering ultraviolet and the visible regions (between 0.3 – 0.9 um). Because the panchromatic sensor is sensitive to a wider portion of the spectrum, it needs less light, while the color sensor needs more light because it is sensitive to a smaller portion of the spectrum. This variation in the amount of energy required to excite the silicon of the sensor made it possible to manufacture sensors with smaller CCDs for panchromatic sensors as compared to the CCD required for the color or the multispectral sensors when they're flown from the same altitude and subjected to the same light source. So at a certain flying altitude we can use a smaller CCD, and therefore smaller GSD, for a panchromatic sensor than for a color sensor. This fact is adopted for the design of imaging sensors on board observational satellites. Imaging satellites usually carry two (or more) types of imaging sensors—the panchromatic sensors with a better resolution on the ground (smaller GSD) but lower spectral quality and the multispectral sensors with a larger GSD but higher spectral quality. Scientists and researchers aware of this disparity took advantage of it by combining the best of both worlds by fusing the high geometric resolution of the panchromatic imagery and the high spectral quality of the multispectral imagery through a spectral merging technique called "Pan Sharpening."

The pan sharpening process fuses the two images (panchromatic and multispectral) together to obtain an image with both high spectral and spatial resolutions. In other words, pan sharpening fuses a higher-resolution panchromatic raster band (panchrommatic, in this case) with a lower-resolution multiband raster dataset. Such fusion produces a multiband raster dataset with the resolution of the panchromatic image where the two images are fully geo-referenced, overlapped and integrated in one new raster image.

To understand the process of pan sharpening, it is crucial to understand the color space transformation. Digital imagery is usually displayed as additive color composites using the three primary colors, red, green and blue (RGB). The RGB color cube (Figure 1) describes the brightness levels of the primary colors. For an eight-bit-based display device, each primary color is represented by a range of digital number from 0 to 255. Therefore, there are 256^3 (or 16,777,216) possible combinations of RGB color variations that can be displayed by such a device. The RGB component is not the only way to describe colors. In the IHS system, the intensity is the total brightness of the color; the hue is the actual color, which describes the shade of the color and its location in the color spectrum; and the saturation is the purity of color relative to gray.

To illustrate the use of this definition of IHS, pastel colors, such as pink, have low saturation compared to the high saturation of crimson. The advantage of the IHS enhancement is that each component can be modified without affecting the other two components. As an example of this, the contrast stretch of saturation can be adjusted without affecting the hue and saturation (as they typically are in the RGB contrast stretch). The previous discussion illustrates that transforming RGB components into IHS components before processing provides better control over color enhancements. Once the image is manipulated in IHS space it can then be transformed back to the RGB color space (Figure 2).

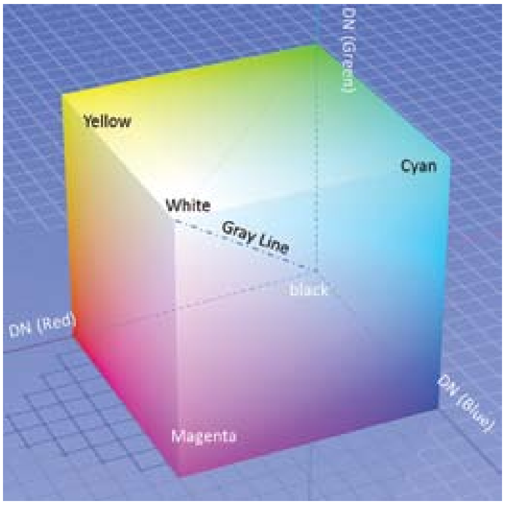

Figure 1. The RGB color cube. X-axis as red values increasing to the left, Y-axis as blue increasing to the lower right and the vertical Z-axis as green increasing towards the top. The origin, black, is the vertex behind the view, the line from the origin of the cube to the opposite corner (white) is the gray line (modified from an illustration adopted from Wikipedia[1]).

[1]http://en.wikipedia.org/wiki/RGB_color_model

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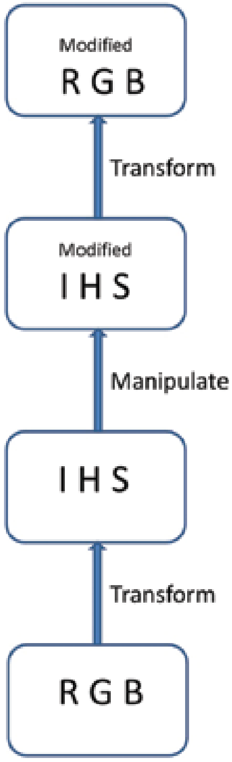

Figure 2. RGB-to-IHS transformation stages.

Researchers have developed many ways over the years to pan sharpen an image; however, the IHS-based method is the most widely used one for its simplicity and ease of computations as well as its resulting high spatial resolution. The IHS-based method fuses imagery by converting the image from the RGB space to the IHS color space. In the IHS-based method, the fused image uses the intensity (I) from the high-resolution panchromatic image but the hue and saturation of the multi-spectral image remain the sole representation of colors in the new pan-sharpened image. This way we obtain a high-resolution multi-spectral image. The details of the transformation are beyond the scope of this article, and readers are advised to refer to one of the many textbooks on remote sensing such as *Remote Sensing and Image Interpretation* by Lillesand, Kiefer and Chipman and *Introduction to Remote Sensing* by James B. Campbell. It is worth mentioning here that a pan-sharpened image is useful in visual interpretation techniques but may have limited use in quantitative analysis due to the compromised spectral quality.

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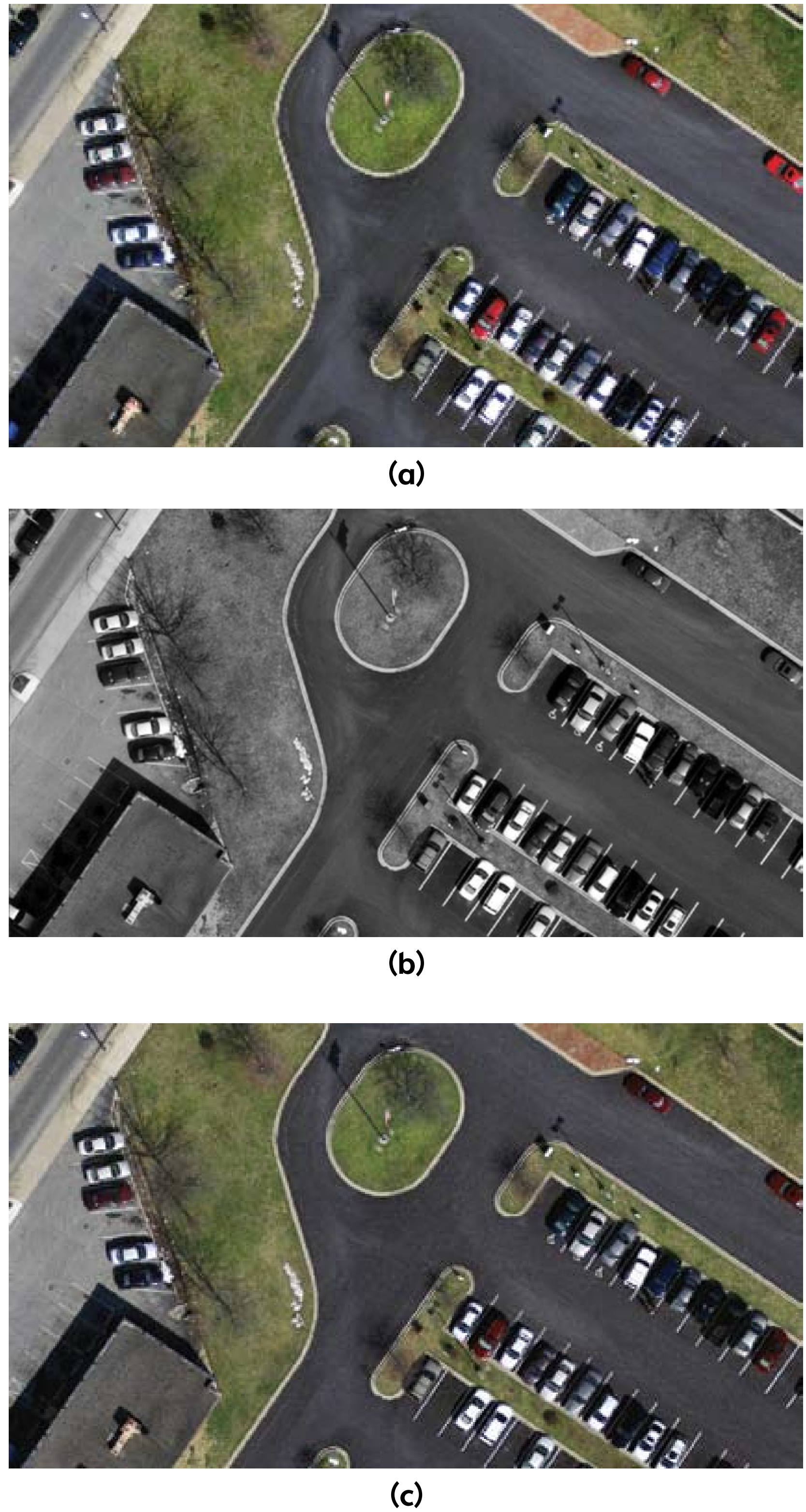

Figure 3. Pan-sharpening example: a) Original multi-spectral image at 25 cm resolution, b) Panchromatic image at 7.5 cm resolution, c) Pan-sharpened multispectral image at 7.5 cm resolution.