Chapter 14: Radiometric Enhancement of Landsat Imagery

Remote Sensing in an ArcMap Environment

Image source: landsat.usgs.gov

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In the next few tutorials, you will gain an understanding of the theory of image enhancement using ArcGIS 10.X. This specific tutorial involves radiometric enhancement.

Introduction to Image Enhancement

**Image enhancement** refers to procedures that remote sensing analysts use to adjust the values in a remotely sensed image to improve its visual qualities for a specific purpose. The brightness values at individual pixels are changed to achieve improved brightness, contrast, color balance, or other qualities.

The visual quality of an image is related to the range of brightness in the image, known as **contrast**. A high contrast image has a narrow range of brightness—mainly blacks and whites. A low contrast image has a wide range of brightness. Usually, excessive contrast is undesirable; as the analyst cannot see features depicted in the intermediate grey that usually form the most important part of an image. On the other hand, lack of contrast is usually undesirable as the analyst cannot the edges that form the see the

Image enhancement is a tool that permits the analyst to apply the level of contrast appropriate for a specific purpose. It is important to recognize that image enhancement is intended to improve the appearance of a specific image for a specific purpose. Because analysts have different objectives, and images have differing qualities, preferred enhancement techniques will vary from one application to the next. Image enhancement focuses entirely on manipulating the appearance of the image, so it is fundamentally cosmetic in nature, and should not be used as input for analytical purposes.

Most remotely sensed images require some form of enhancement because they use only a small range of the brightness available to a computer display, so many of the features depicted on the image are not visible to the analyst. As a result, in its original form, the image may not be suitable for its intended use. Image enhancement applies a strategy for expanding the range of brightness use to display the image, thereby revealing features that might not be visible in the original version.

Enhancing image dynamically in a Viewer is much faster than writing permanent image file for every enhancement operation (and also saves disk space). Therefore, while experimenting to find the desired enhancement, use dynamic (temporary) enhancement in a Viewer. Once you achieve the enhancement that you want, it can be permanently saved.
Image enhancement can be best discussed in the context of the frequency histogram of a digital image. A frequency histogram displays image brightness along the horizontal axis, and numbers of pixels at each brightness level along the vertical axis. The shape of a specific histogram is related to the features represented a scene, and conditions under which the image was acquired.

**Linear Contrast Stretch** extends the range of brightness through a systematic expansion of image brightness to occupy the full range of brightness available by creating new intermediate values to generate the necessary range of brightness.

**Histogram Equalization** expands the range of brightness by sliding the brightness along the brightness scale so that they occupy the full range of brightness available in the display. The histogram of the enhanced image shows gaps between the brightness values because they have been separated to create a wider range of brightness in the image.

There are a great variety of digital image enhancement techniques. The choice of particular technique(s) depends on the application, data available, experience and preferences of image analyst. In this and the next two tutorials, we will cover the three most important and widely used groups of enhancement techniques:

- **Radiometric Enhancement** - Enhancing images based on the values of individual pixels (this tutorial)
- **Spectral Enhancement** - Enhancing images by transforming the values of each pixel on a multiband basis (Band Ratios, Vegetation Indices, & Tasseled Cap - see Tutorial 15. Spectral Enhancement of Landsat Imagery.)
- **Spatial Enhancement** - Enhancing images based on the values of individual and neighboring pixels (see Tutorial 16. Spatial Enhancement of Landsat Imagery)

**Using ArcGIS as a Viewer for Radiometric Enhancement**

Open a map document and load the 7-band composite image that you created in the tutorial on Creating a Composite Images from Landsat Imagery. Be sure your **Image Analysis** window is open. Set your image with band combination 4-3-2. *(Note - you can also use these tools on each of the bands as separate images.)*

Left-click on the image name in the **Image Analysis** window. Once you click on it, it should activate most of the buttons in the **Display** window. First, we are going to examine each one of these buttons and their effects on the viewer. We will then examine histograms (next
section) in two areas, within the **Image Analysis/Display** window and within the **Layer Properties/Symbology** dialog box.

Using the **Display** window, you can change the **Contrast**, **Brightness**, **Gamma**, and **DRA** (dynamic range adjustment) of the image in the map document window by either moving the sliding bar or placing a numeric value in the box next to the sliding bar. Go ahead and change the values, one at a time. Observe the changes in your display (note these are only changing the display, not the original image). Each one changes the display in different ways. **Brightness** will make the image appear lighter or darker. **Contrast** changes the range of differences between the darkest and lightest objects. **Gamma** controls relationships between the brightness of original scene and that on the display. (For example, at a gamma of 1.0, the two images will use the same scale of brightnesses, whereas at gammas of 0.5 or 1.5, the display shows, respectively, either compressed, or expanded, scales of brightness relative to the original.) These tools are useful when doing image classification to help you discern different features within the image.
We will discuss the list of options within the blue oval in the tutorial on Spatial Enhancement of Landsat Imagery.

*Transparency* displays the image so you can see the image below it. If the image below is an aerial photo, you would be able to see and associate the various brightness values to specific objects. For example, by adjusting the transparency of the Landsat image (below left) from 0 (not transparent) to 50 (partially transparent) (below right) you can see that the very bright area at the top and center corresponds to a building within a parking lot.

To set these values back to the original values, just hit the reset button, which is the icon for each tool.

By placing a checkmark in the box next to *Background* you eliminate the no data value in the display (ArcMap makes Raster files square by adding no value boxes), so you will see the actual Landsat scene without ArcMap filling it in.
Finally if you hit *Zoom to Raster Resolution*, the display will zoom in on the image.

Before proceeding to the next steps, please hit the *reset* button on all the *Display* buttons, so we are back to the original images.

**Histograms**

As stated above, histograms plot the frequency values of the digital numbers (DNs) (x-axis) against the number of pixels with that value (y-axis). (Remember, the shape of the histogram is determined by the features represented in the image, and their brightnesses.) We will discuss histograms in two different areas within ArcMap.

The first area where ArcMap displays histograms is in *Layer Properties/Symbology* tab. You will find the histogram button in the middle of the dialog box. Before clicking on this button, notice the *Stretch Type – Percent Clip*. 

Left-click on the down arrow and you find a list of different type of histogram stretches available in ArcMap. **Percent Clip** is the default; this method eliminates the minimum and maximum values ends of the histogram based on a percent (the default is 2.00). You can change these values by changing either the standard deviation or the percent of the clip. (For more information see ArcGIS on-line help.)
Now, left-click on this button. It displays one histogram – the red band. With a 4-3-2 band combination, which Landsat band is this? (Answer – near infrared). For this particular band, you see the minimum, maximum, mean and standard deviation values. By left-clicking on either the **Green** or **Blue** tabs, you can look at the histograms for the other two bands.

Why would each histogram look different? (Answer – because each band has a different range of DN’s.)

If you change the histogram stretch type, you must click on **Apply** in order for the change to take effect. Change the histogram stretch type to **Standard Deviations**. What happened to the image? Now look at the histogram for the red band. ArcMap shows you the new histogram but also shows the original histogram from the **Percent Clip** method grayed-out so you can compare before/after views of frequency distributions as you make changes.
Now, let’s explore the other area where you can look at histogram. Before closing out the Layer Properties/Symbology dialog box, reset the stretch method to Percent Clip and click on Apply.

The second area where histograms are displayed are in the Image Analysis window. To use this tool, highlight the image that you wish to examine using icons visible at the top of the window in order to enable the display tools. Underneath Background, you see the Percent Clip method and a button that looks like a histogram.
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Make sure your image is zoomed out to the entire Landsat scene and left-click on the **Histograms** button. This gives you all three histograms for the three different bands that you are displaying (using the **Percent Clip** method).

Remember, for 4-3-2, red is for the near-infrared band (Landsat Band_4), the green for the red (Landsat Band_3), and the blue for the green (Landsat Band_2). The numbers below each histogram correspond to the value of the arrows within the histogram and the values that correspond to the **Min-Max Percent** numbers.

You move the arrows to identify different values within the histogram. When moving the arrows, you do this as a separate action on each band’s histogram. To change the **Min-Max Percent** values, just enter the new value (hit enter after changing the values). As an example, enter 20 for the minimum and observe what happens to the image and the histograms—you can see that you have changed the red and green bands only slightly, but have lost most of the values in the blue band.

Is it reasonable to want to change the histograms using the exact same percent? Why or why not? *(Hint – each band is useful for different reason. Should you address each one independently?)* Would
you use the same method to assist in feature identification -- forest areas versus the city? Why or why not?

Additional question - What is the DN at the peak of the near-infrared band? What does this peak mean? (Answer – this DN has the highest number of pixels.) Don’t worry about permanently changing the display - by clicking on the counter-clockwise arrow (red circle) for any of these, you will reset it to the original values.

Now let’s do another one and see how it changes the image. Change the stretch method to Min-max. How has the image and histogram window changed? (The Min-Max Percent at the bottom is gone and it includes the entire range of values for each band). You can now perform a contrast stretch separately to each band.

You can adjust the minimum value by either sliding the arrow or entering the value into the left box. To change the maximum value, enter the value into the right box.

Explore the various methods of histogram stretch with different band combinations. Which methods are best will depend on the purpose of your project.

You can also use ArcMap to perform density slicing to enhance your image. Density slicing differs from contrast stretch in that it assigns colors to specific brightness values. The colors do not add additional information, but simply permit the analyst to make sharper distinctions between brightness classes in the image. You cannot perform density slicing on a composite image within
ArcMap,--density slicing can only be accomplished on each individual band image that you received with your Landsat download. This procedure is beyond the scope of this tutorial.

We will discuss further Image Enhancement techniques in the next two tutorials on Spectral Enhancement of Landsat Imagery and Spatial Enhancement of Landsat Imagery.

As a review: Spectral Enhancement transforms the values of each pixel on a multiband basis (Band Ratios, Vegetation Indices, & Tasseled Cap) and Spatial Enhancement enhances images based on the values of individual and neighboring pixels.
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