GE 5113/4113 Lab 04
Image Processing I
Display, Contrast Stretch, and Band Ratios
Feb. 21, 2018

You will use the image processing package ENVI in order to learn some of the basics of image processing, and will prepare an on-line (Word) illustrated report of approximately 4 or 5 pages summarizing your observations regarding various image processing operations and results.

If you haven't already done so, read the general computer instructions handout. Create the directory for your local files, as explained there, either download the Lab 04 Data zip file from the class web site <**`http://geofaculty.uwyo.edu/rhowell/classes/remote_sensing/`**> and unzip it into that temporary directory, or, if it is up and running, copy the following two files from the shared directory on **`uw-bulk: TM17June91Lar`** and **`TM17June91Lar.hdr`** .

Part A: Loading and Displaying an Image:

1. Start **`ENVI 5.x Classic`** by navigating from the **`Start`** menu through **`ENVI 5.x / ENVI 5.x Classic (64-bit).`** This "Classic" mode uses an interface which is very different than the new default interface you get by just starting **`ENVI 5.x/ENVI 5.x .`** All the lab instructions are written for the classic mode, so at least for these labs, use that classic mode.

2. Click on **`File>Open Image File`** then navigate to your local directory and select **`TM17June91Lar`**. This file is in ENVI format, so all TM bands will open at once – these should appear in the "available bands" list. The data set includes all 7 TM bands, including the thermal IR image (Band 6), for a 900 x 800 subscene from a June 1991 TM image of Laramie. (Both the main data file and a HDR file should be present which contains auxiliary data. You can select either one.)

3. Select the **`Gray Scale`** `"radio button"` then select Band 3 (the red band) from the 7 bands offered.

4. Click on **`Load Band`**, and that band should be displayed in three windows. The "scroll" window shows the entire subscene at low resolution. The "image" window shows a segment of the image in full resolution. The "zoom" window displays a still smaller segment at variable magnification. The movable red boxes show the portion displayed in the next larger scale window and dragging them shifts the portion displayed.

5. Experiment with the three windows until you are familiar with the various display features. If you have enough screen space so that you can enlarge the main Image window to cover the full data set, the no-longer-needed scroll window will disappear. Try to do that.

6. In the **`Available Bands List`** window, select band 6 from the list.

7. Click on the **`Display #1 ▼`** button, select **`New Display`**, then **`Load Band`**, and it should create a new set of three windows for band 6. (You could also have chosen to load it into the windows originally used for band 3.)

You should now have both the red band image and the thermal image on the screen. Compare the differences in image resolution and the response of objects. Note that the thermal band has been "resampled" to 30-meter pixels, but still contains only the original 120-meter resolution of the thermal band. Therefore 4×4 blocks of pixels are identical. Try to estimate the smallest feature you can see in each band. For example, what detail can you see on the golf course? Write a few sentences about this in your report.

Close the Band 6 image. For the following use the Band 3 (red) image.

Part B: Contrast Stretch the Image:

The following functions control how the original range of data numbers are mapped into the 0=black to 255=full brightness range of the display itself. The various histogram windows let you see graphically what brightness mapping is being used and how your data values are distributed.

Examine the various stretching functions, save versions of the stretched images and the histograms in your report , and describe in a couple sentences what each stretch is doing, including what aspects of the image it makes easy to see, and what aspects it makes hard to see. For example is the image mostly dark with just a few bright spots? At the dark and bright end can you distinguish detail or are significant regions saturated all black or all white?

1. On the Image window menu, click on `Enhance` and `Interactive stretching`. A histogram window should appear, described below.

2. On the Histogram window menu, select `Defaults->[Image] Linear 0-255`. The `[IMAGE]` means use pixels displayed in the image window, and the `Linear 0-255` means display the data values 0 to 255 directly as brightness levels 0 – 255, without modification. The output histogram shows how many pixels on the display have each of the possible 0 – 255 brightness levels, where 0 is black and 255 is white. The output histogram should be identical to the input histogram, showing that the data are displayed without contrast enhancement. Use the `Alt+Print_Scr` copy function (`Alt+F14` on the Mac keyboards) to save copies of the main image window and the histogram window in your report.

3. Now select the following additional default stretch routines (`linear`, `linear 2%`, and `gaussian`). By examining both the displayed image and the histograms, compare what each one does to the distribution of image values. The output histogram should be a clipped and perhaps stretched version of the input one. Look at the overall shape of the histogram envelope (where are peaks and valleys?) to understand how it has been stretched and clipped. Ignore the vertical lines or bars in the output histogram – just try to recognize the features in the overall envelope.

   For each of these three additional stretches, save copies of the main image window and the histogram to your report. Write a few sentences about each, comparing how they are stretching the brightness values and how that effects the images. Once again, what is the overall brightness level in the image. Are parts saturated white or black? How well can you see detail over a wide range of brightnesses?

   If you have time after completing the rest of the lab, return to this and evaluate other (non-default) stretch functions (such as `piecewise linear` and `arbitrary`) that are offered under `stretch_type`.

Part C: Scatter Plots and Band Math

Scatter plots, where for each pixel the brightness in one band is plotted versus the brightness in another band, can show patters in how those two brightnesses are related. Band Math provides a general way to compute a new value for each pixel, based on some formula and the original pixel values.

To see how the brightness in the blue channel (Band 1) is related to the brightness in the green channel (Band 2) do the following:

- Create a scatter plot: From the image menu: select `Tools>2-D scatter plots`, then tell it to plot band 2 as X and band 1 as Y. Click OK.

- Adjust the x and y range of the scatter plot to cover the full 0 – 256 range of TM data:
  Select (`Options>Set X/Y Axis Ranges`) then enter the appropriate numbers.
  You can drag a corner of the plot to make it larger and easier to read.
  Make sure the plot window is "active" then use `Alt+Print_Scr` to copy the scatter plot to your report.

- From the scatter plot estimate the line of best correlation. To do that:
  estimate the (X_{min},Y_{min}) coordinates of the lower left of the main data cluster, and the (X_{max}, Y_{max}) coordinates of the upper right of the main data cluster. There will always be small numbers of scattered points outside the main cluster, and in this case a less dense cluster of points which extends to the upper left of the main cluster near the maximum. Ignore those – you want to find the edges of the main data cluster. Note that with the full range specified as 0 to 256, the tic marks and numbers are at at intervals of 16:
  0, 16, 32, 48, **64**, 80, 96, 112, **128**, 144, 160, 176, **192**, 208, 224, 240, **256**.

  Using the x-y coordinate pairs, find the slope and intercept for the line of best correlation and record them in your report.

  slope = $(Y_{max}-Y_{min})/(X_{max}-X_{min})$

  If the cluster of points extends to x=0 you can just read Yintercept off the plot, otherwise use
  $Y_{intercept} = Y_{min} - \text{slope} \times X_{min}$

  You should get a pattern where the brightness in blue increases almost linearly with the brightness in green, because most surfaces which are bright in one are also bright in the other. However the blue brightness does **not** go to zero even when the green brightness does, presumably because of atmospheric scattering.

  As we will see in the next part, often we want to ratio the brightness in one band to the brightness in another to take out these general light vs. dark patterns and look at only how the "color" changes. For a simple surface affected only by brightness, not color changes, the ratio would be constant. However if we ratioed uncorrected blue to uncorrected green we would **not** get a constant ratio -- the blue/green ratio would increase towards infinity the closer the green color got to zero. We can however use "Band Math" to correct the blue channel before we perform the ratio.

- Correct band 1 using the parameters you just estimated.
From the main menu select: **`Basic tools>band math.`** Enter the expression (B1 – $Y_{intercept}$) / slope in the appropriate box (using your numbers for $Y_{intercept}$ and slope) then click the **`Add to List`** button. In the list of expressions make sure the one you added is highlighted then click **`OK`**.
When you click **`OK`** the system will complain it doesn't know what **`B1`** is. That is just a symbol (chosen to be memorable), but you need to tell it that **`B1`** is really band 1. To do that select that band from the list which should appear, then click **`OK`**. The system will also want to know where to save the data. Use the **`Choose`** button to pick a reasonable file name like **`adjusted_band_1,`** and while you are doing this, at least for the first file, you will also want to choose to place it in your temporary directory, rather than someplace random on the machine. Finally, click **`OK`** to save the result. Besides saving the file, you should notice this data appears as a new entry in the **`Available Bands`** window list.

- Display a new 2-D scatter plot, now showing the adjusted band #1 as Y and the original band #2 as X. Be sure to adjust the X,Y display range to 0-256. <u>Save it to your report</u>. If you have properly corrected the data the points should scatter around a line of slope 1, going through the origin. <u>Discuss briefly how well it actually shows that pattern.</u>

  Although we won't actually do this here, if you did now ratio adjusted_band 1 to band 2, most pixels would have a value of approximately 1, and slight deviations from that value would actually useful information about the color -- being high for a truly blue surface, and low for a truly green one.

Part D: Soil characteristics determined by band ratios.

Theory:

Band ratios, that is, the ratio of the flux in one band to that in another, can often serve as diagnostics tools for determining soil, mineral, and vegetation composition. When properly applied, band ratios suppress "irrelevant" variations in band brightness, for example those caused by lighting geometry or slope, while highlighting the important relative band differences.

In the above part B we corrected the band 1 data before ratioing it, and we did that demonstration with the blue data because the scattering effect is so dramatic there. For other wavelengths perhaps we should also correct the data, but for simplicity, and because the scattering is so much smaller, we will just ratio uncorrected data.

In this exercise we will compute three different band ratios to determine the following three properties of the land and will form and save a composite image where each ratio (or property) will be <u>displayed</u> in one of the RGB channels:

1. R channel: Redness of the soil (bright values = abnormally red soils)
2. G channel: Vegetation (bright values = lush vegetation)
3. B channel: Clay content of the soil (bright values = high clay content)

In this exercise we will use the following ratios to measure the above properties:

Display	*Property #*	*Property*	*Band Ratio*		
RED	*#1*	*(soil redness)*	*Band 3 (red)*	/	*Band 2 (green)*
GREEN	*#2*	*(vegetation)*	*Band 4 (0.88 µm)*	/	*Band 3 (red)*
BLUE	*#3*	*(clay content)*	*Band 5 (1.65 µm)*	/	*Band 7 (2.22 µm)*

This last ratio works because clays will be dark in Band #7 due to OH absorption. Think about why the other ratios work.

For example, let's suppose we are observing a gray surface which should look the same at all wavelengths, except that varying slopes and lighting geometry change the total brightness. Since both band brightnesses should go up or down together, computing the brightness ratio of any two bands should suppress this variation, giving an image which is everywhere just some constant ratio. Any other observed ratio value would then indicate a different type of surface.

Outline of ENVI Procedure: (In the following I'm giving you a general guide, but not exact step-by-step instructions. To find out how to perform the operations explore the ENVI menus, use the ENVI help system, and if necessary ask the instructor.)

- Display a 3-band false-color composite image (initially using bands 4,3,2) in RGB. For consistency, move the box in the Image window so that the Zoom window shows the golf course.

- Compute the ratio of band #3 / band #2 using the main ENVI menu item **`Transform->Band Ratios`**. From the available bands list select band #3 for the numerator, and band #2 for the denominator. Once these are selected click the **`Enter Pair`** button, then make sure the desired pair is actually selected in the list of pairs, and click **`OK`**.. **`Choose`** a reasonable name for the output file like **`ratio_3a_over_2`** and be sure you are saving it in your **`C:/temp`** directory.. You should save it in floating point format, which will most likely be the default. <u>Save a copy of this image in your report.</u>

- Once you have completed the above procedure for band #3 / band #2, repeat this last step to produce ratios for the band #4 / band #3 and band #5 / band #7.

- Now that you have computed the three desired ratios, display them all simultaneously as a 3-band color composite image with the "soil redness" ratio in the red channel, the "green vegetation" ratio in the green channel, and the "clay content" ratio in the blue channel. The various ratios you need should appear in the "available bands" list.

- Use a **`Gaussian contrast stretch`** to enhance the resulting display.

- <u>Save your final color image.</u> Rather than using the simple screen capture routine, use the following procedure to save a good copy of the full Landsat frame:
  From the image menu click **`File>save image as.`** Then select the options to save it as an image file, and select JPEG as the image type, so Word can read it. From Word, paste the image file into your report. (Be sure you really saved a color version. If you check the wrong boxes, you might only get a gray-scale one.)

- <u>Examine and interpret the image, discussing it in your report.</u> What other colors are prominent? For each prominent color, what does that color imply for the #1, #2, and #3 property values? What types of terrain correspond to those regions. For example, regions near the river (and elsewhere) are cyan. Which two property #'s are high for cyan? What type of terrain corresponds to cyan: vegetation? clays? red rocks? Why are those two property #'s high for that type of material? Repeat this for the other colors which are prominent on your image.

Summary

In this lab you have learned how to display images, measure how one band correlates with another, correct observations using band math, and compute band ratios.

Your lab report should contain:

1) Estimates of the smallest features you can see in both the visible and the thermal Landsat channels.

2) Examples of images and histograms for **`Linear 0-255`**, **`Linear`**, **`Linear 2%`**, and **`gaussian`** stretches, along with a brief discussion of how they differ.

3) Scatter plots for the blue vs. green channel, before and after correction of the blue, plus the slope and Y intercepts values you used to correct the blue data

4) Three individual band-ratio images

5) An RGB image showing three different color rations givign (soil redness), (vegetation), and (clay content), plus a discussion of why various parts of that image have the apparent colors (and color ratios) that are evident.