7. RECTIFICATION (GEOMETRIC CORRECTION) OF IMAGES AND RESAMPLING

Aim: To introduce you to methods of rectifying images and linking them to geographical coordinate systems by resampling.

Objectives: By the end of this tutorial you will have learnt how to use a series of ground control points (GCPs) of known longitude and latitude to rectify an AVHRR image and generate a resampled image with each pixel having latitude and longitude coordinates like a map.

This tutorial investigates the **Image, Rectify** and **Image, Resample** options of the *Bilko* menu using an AVHRR band #2 image of Northern Ireland and SW Scotland (**AVHRR_Mulls#02.bmp**), recorded in the near infra-red (wavelengths 0.72–1.10 μm).

So that you can judge how well the rectification has worked we have downloaded a geometrically corrected United States Geological Survey (USGS) MapGen 1: 250,000 image that shows the coastlines of the area from http://rimmer.ngdc.noaa.gov/coast. This file has been saved as **Mulls_coastline.gif**. To save you time we have also set up a Table document (**Mulls_coastline.tbl**), which links a series of ground control points (GCPs) in the geometrically corrected coastline image (with known longitude and latitude) with a corresponding series of points in the AVHRR image for which we only know the column and row coordinates. You will need to add five new GCPs to properly rectify the AVHRR image and will learn two different ways of doing this.

Activity: If you have any images open, please close them. Open the image file **AVHRR_Mulls#02.bmp** and **Mulls_coastline.gif.** Examine the two images. Note that Longitude and Latitude coordinates are displayed in the Status Bar for any point that you click on in the **Mulls_coastline.gif** image and that **View, Coords** is checked. By contrast, note that you cannot set **View, Coords** in the **AVHRR_Mulls#02.bmp** image.

Note also that because the AVHRR band#2 sensor is recording reflected near infra-red radiation that the land is bright because vegetation reflects near-IR radiation strongly. By contrast, the sea is very dark because water absorbs near-IR radiation. Note that the more richly vegetated lowland areas are noticeably brighter than the sparsely vegetated higher ground.

Note that the **Mulls_coastline.gif** image consists of only two values. The coastline is black with pixel values set to 0, the remainder of the image is white with pixel values set to 255.

Question 1: How many columns and rows does the **AVHRR_Mulls#02.bmp** image have?

Question 2: How many columns and rows does the **Mulls_coastline.gif** image have?

Question 3: What is the longitude and latitude of the top left corner of the **Mulls_coastline.gif** image?

Question 4: Across how many degrees of longitude (W–E) and latitude (N–S) does the **Mulls_coastline.gif** image extend?

Using the **Mulls_coastline.gif** as a "master" image we have matched a series of pairs of GCPs of known longitude and latitude on this image to a series of points of known column and row coordinates on **AVHRR_Mulls#02.bmp** "slave" image. These GCP pairs are stored in a Table document **Mulls_coastline.tbl**. However, before you use this we will take you through what you would normally do if starting out to rectify an image.

Activity: With the ***AVHRR_Mulls#02.bmp*** image selected as the active window, select **Image, Rectify** from the menu. This opens the **Rectify** dialog box (see right). Inspect this and note that because you have only one image with and one without geographical coordinates open, the **Master Image:** is already set to ***Mulls_coastline.gif*** and the **Slave Image:** to ***AVHRR_Mulls#02.bmp***. This is what you want, so don't change anything but just click on OK .
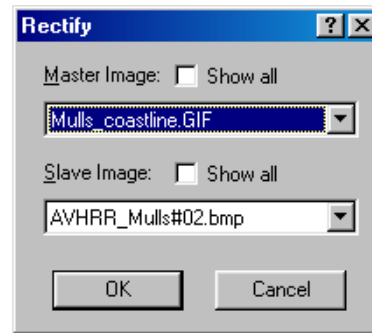
Examine the blank table which appears and note that it has four columns: **Description** (this will usually contain place names corresponding to each GCP); **Master:** which is set to ***Mulls_coastline.gif***; **Slave:** which is set to ***AVHRR_Mulls#02.bmp***; and **RMS:** which stands for Root Mean Square error.

At this point you would normally start entering 20–30 GCP pairs from points fairly evenly distributed across the master and slave images. To save you time, you will only enter one (for Malin Head, see Figure 7.1 below) in the blank table and then open the previously prepared table and enter a few more GCPs there.

Figure 7.1. Map showing positions of three of the GCPs to be entered.

Activity: Position the mouse pointer over GCP #000: and click on it. It should become a blank box. Type in *Malin Head* as the description for the GCP and press the *<Tab>* key to move to the second column. Now click on the ***AVHRR_Mulls#02.bmp*** image and try to position the image cursor on the NW tip of Malin Head using the Status Bar to guide you as to where the land (bright) : sea (dark) boundary is. When you are satisfied that you've got the image cursor in position, click on the ***Mulls_coastline.gif*** image and position the image cursor on the corresponding point on this image. When you are satisfied that you've got the cursor correctly positioned, press the *<Insert>* key.

A yellow cross with 000 beneath it will appear on both images. The longitude and latitude coordinates of the GCP will appear in the **Master** column of the table. The column and row coordinates of the GCP will appear in the **Slave** column of the table. Congratulations! You've successfully set up your first GCP. The first line of the table should now look something like this:

GCP #000: Malin Head	(007°24'20.32"W, 55°22'24.72"N)	(0008, 0145)

Activity: Before proceeding, note that unchecking the GCP checkbox changes the colour of the GCP to cyan on the two images. Only checked GCPs are included in the rectification

process. Also note that if you hover the mouse pointer over the centre of the GCP cross on the images then an information box appears with the Description information for the point.

Close the Table without saving it. Note that the GCPs disappear. Now open the table *Mulls_coastline.tbl*. Note that many GCPs appear on both images. Inspect the table document and the distribution of GCPs on the images.

20 GCPs are filled in for you (GCP #000 to #019). There is a lack of GCPs in the north-east and south-west of the images and if you are to achieve good rectification you need to enter some here. You will enter three of these from Table 7.1 which is set up as if someone had used a map to find out longitude and latitude of three points on the *AVHRR_Mulls#02.bmp* image for which column and row coordinates are known. You will later enter a further two GCPs using the same method that you used for the Malin Head GCP.

Table 7.1. Three GCP pairs showing longitude and latitude of three points on the *AVHRR_Mulls#02.bmp* image.

Description	Master	Slave
GCP #020:	3°41'05.00"W, 56°01'34.85"N	452, 123
GCP #021:	3°10'59.51"W, 55°59'20.40"N	499, 132
GCP #022:	6°16'20.32"W, 54°34'54.72"N	100, 237

Activity: Click directly on the master image column for GCP #020. You can enter the first coordinates as: 3 41 5W 56 1 34.85 *or* 3o41'5"W 56o1'34.85"N *or* 3 41 5W, 56 1 34.85N. All will work. Pick a format that suits you. [*Note:* you must specify if coordinates are W or S but do not have to specify if N or E]. When done press the *<Tab>* key to move to the slave image column. The column and row coordinate 466, 125 (or similar) should appear, which is where the program predicts the point will be on the *AVHRR_Mulls#02.bmp* image based on other GCP pairs and the current transform. You should enter the correct coordinate (452, 123) and press the *<Tab>* key. The RMS errors for each point and the overall average RMS are recalculated as the new GCP pair is entered.

Repeat the process for GCPs #021 and #022 and check that values are all correct. To see where the new points are, uncheck the three GCPs' checkboxes so that they appear in cyan on the images. Having seen where they are, recheck them so that all checkboxes are ticked.

To complete the table, two more GCPs – one at the NE end of Loch Lochy and one at the SW end of Lough Neagh (see Figure 7.1) – need to be added. You will use the same method as you used for Malin Head.

Activity: Position the mouse pointer over GCP #023: and click on it. It should become a blank box. Type in *NE end of Loch Lochy* as the description for the GCP and press the *<Tab>* key to move to the second column. Now click on the *AVHRR_Mulls#02.bmp* image and try to position the image cursor on the NE end of Loch Lochy (Figure 7.1) using the Status Bar to guide you as to where the land (bright) : water (dark) boundary is. When you are satisfied that you've got the image cursor in position, click on the *Mulls_coastline.gif* image and position the image cursor on the corresponding point on this image. When you are satisfied that you've got the cursor correctly positioned, press the *<Insert>* key. Repeat the process for GCP #024 at the SW end of Lough Neagh (Figure 7.1). Check their positions on the images.

The two new GCPs should look something like this in the rectification table:

GCP #023: NE end of Loch Lochy	(004°50'20.32"W, 57°00'54.72"N)	(0377, 0012)
GCP #024: SW end of Lough Neagh	(006°36'20.32"W, 54°31'24.72"N)	(0057, 0240)

Congratulations, that's enough GCPs to rectify the image. You will now carry out rectification of the *AVHRR_Mulls#02.bmp* image using two different transforms so that you can compare their effectiveness.

Activity: Make sure all GCPs are checked. To find out what transform is being used, right-click on the rectification table document and select the **Transform** option. This should be set to **Linear**. [Note that the other two options are Quadratic and Cubic]. Now that all GCPs are entered and the transform is set, click on the Copy button on the toolbar, select the *AVHRR_Mulls#02.bmp* image and then click on the Paste button to fix the GCP pairs.

You are now ready to resample the image and map it onto the master image's coordinate system.

Activity: Select **Image, Resample** and a **Resample** dialog box appears with four tabs (Window, Pixel, Image, Interpolation). Inspect this and answer the questions below.

Question 5: What are the three methods of interpolation which are supported?

Question 6: What is the width and height of the pixels in the rectified output image set to?

Activity: Select **Cubic convolution** as the method of interpolation and click on the **Apply** button to make this take effect. Leave all the other settings alone for now and select OK to carry out the resampling. Inspect the output image that has been rectified using a linear transform and note how the geometry has been significantly altered. In particular it is now clear that the image "north" is several degrees different to true north.

You will now compare the rectified image to the master image coastline map to see how good the rectification has been. To do this you will connect the new image and the master image and then use a formula document to draw the coastline as a white line on the new image.

Activity: Use the **Image, Connect** function to connect the rectified (resampled) output image to the *Mulls_coastline.gif* image and use the **Selector** toolbar to designate the rectified image as image 1 (@1 in formulas) and designate the *Mulls_coastline.gif* image as image 2 (@2 in formulas). Now open the formula document *Draw_Mulls_coastline.frm*. Copy the formula and Paste it on the connected images window. Inspect the resultant image.

Question 7: How well does the resampled image fit the original master image coastline?

You will see that a linear transform is too simple to give the required result. The curvature of the Earth means that at least a quadratic tranform is needed to warp the AVHRR image and fit it to the master image coastline map.

Activity: Close the connected images window and the resampled image without the coastline added. Click on the rectification table and make a note of the average RMS value (in column header). Change the transform setting to **Quadratic** and note how the value improves dramatically from around 5 pixels to less than 1.5 pixels. Now that the new transform is set, click on the Copy button on the toolbar, select the *AVHRR_Mulls#02.bmp* image and then click on the Paste button to fix the transform.

Select **Image, Resample** and in the **Resample** dialog box select **Cubic convolution** as the method of interpolation again (don't forget to click the Apply button!). Carry out the resampling and connect (**Image, Connect**) the rectified (resampled) output image to the *Mulls_coastline.gif* image as before. Finally, copy the formula (*Draw_Mulls_coastline.frm*) and paste it on the connected images window. Inspect the resultant image. Compare to the linearly transformed image with the coastline added.

You will see that you now have an almost perfect fit between the two images. Congratulations, you've mastered the basics of rectification and resampling!

To finish this tutorial you will now apply your rectification table to band #4 of the AVHRR image (*AVHRR_Mulls#04.bmp*).

Activity: Firstly save the *Mulls_coastline.tbl* with your new GCPs in it. Then close all files EXCEPT *Mulls_coastline.gif* and *Mulls_coastline.tbl* which are still needed.

Now open *AVHRR_Mulls#04.bmp* and right-click on the *Mulls_coastline.tbl* table and select the **Change View** option. Click on the **Slave Image:** drop-down list and select *AVHRR_Mulls#04.bmp* as the new slave image. Click on OK and the GCPs are transferred to the new image. Using a quadratic transform (and not forgetting to copy and paste the rectification table to the new image), resample *AVHRR_Mulls#04.bmp* to the master coastline image. When you have finished close all images.

For further practice at geometric correction using a false colour composite of a large AVHRR image of the Mediterranean, there is a **mini-lesson** available (*Mini-lesson01_Geometric_correction.pdf*).

Quite often you need to exchange rectified images between different software packages or you may be sent binary "flat file" images without any coordinates attached, but which have already been geometrically corrected to a geographical coordinate system such as Universal Transverse Mercator (UTM) or latitude and longitude. In such cases, at least the coordinates of the top left of the image (the image "origin") and pixel dimensions will normally be known. Armed with this information you can apply coordinates to the image. The first part of the next section describes **how to "edit" the coordinates** to do this.