

GEO/EVS 425/525 Unit 9

Aerial Photograph and Satellite Image Rectification

You have seen satellite imagery earlier in this course, and you have been looking at aerial photography for several years. You are aware that the swath of the satellite over the earth's surface is diagonal, so that the imagery is not referenced to any standard reference system. An aerial photograph is equally unlikely to be referenced to a standard reference system.

In this exercise, you will take an aerial photograph of downtown Cleveland and a satellite image from northeast Ohio and rectify the photograph and a portion of the satellite image to the UTM system. The former is a raw image, and you will use it for a basic examination of image rectification. For the latter, you should choose the same quadrangle you chose for Unit 6. You will take some of the DEM-based and DLG-based information you derived for that unit and superimpose it over your satellite imagery. Your strategy in carrying out this exercise will be [1] examine the image to see what it contains, [2] locate your quadrangle roughly on the image, [3] bring up an image that will define ground control points, [4] compute the transformation matrix, and [5] resample the image. There are other ways you might rectify an image, but this is the easiest and the most straightforward. First, open a second viewer. You will need two: one for your image and the other for a reference image. You can use either the split Geospatial light table or two standard viewers.

Rectifying the Aerial Photograph

There are four aerial photographs in the "NASA Aerial Photographs" directory on the R: drive. You can pick any one of them. Put your chosen photograph in one of the viewers you have open. Place an appropriate reference file in the other viewer. You can choose any reference files you want (within reason); the most appropriate are probably the road files cl127ord and cl303ord and the hydrology files cl1270hy and cl303ohy.

Open ImageInfo. How many layers does the aerial photograph have? Which ones are you looking at? How big is the image? That is, how many rows and columns does it have? What skip factor is being used? What does skip factor mean?

Also in ImageInfo, what reference system is being used? Note that there is always a reference system, even if it is simply rows and columns. Do you remember reprojecting your quadrangle from UTM to State Plane? You *must* have a reference system if you are to change from one system to another. And since you will be changing the aerial photograph from whatever it is to UTM, it must have at least a rudimentary reference system.

Return to the first viewer. Click on Raster-Geometric Correction on the viewer menu bar. The Set Geometric Model dialog opens. Select "Polynomial" and click on OK. Two windows open, one of which, the Geo Correction Tools dialog, is quite small and easy to overlook. The larger dialog is the Polynomial Model Properties dialog. Close the Polynomial Model Properties dialog. You will deal with the parameters of this dialog later. The GCP Tool Reference Setup dialog opens. The default setting is "Existing Viewer." You can record ground control points, or GCPs, from many sources: a digitizer, an ASCII file, or a viewer. Since your reference GCPs will be in an existing viewer – that is viewer # 2 – click OK. If you were taking your GCPs from one of the other possible sources, you would indicate the source and instead of working from one viewer to another would be working from a single viewer to the thing you indicated as the source of your reference points. But the default "Existing Viewer" works for now. When you click OK, you are asked to click in the viewer containing the ground control points to select for reference coordinates. Click in viewer # 2, in which you have your georeferenced DEM and DLGs. The Reference Map Information dialog opens, containing the reference system information from this viewer. It is not editable, but it is asking you to verify that the reference system is correct. Click OK.

At this point, two small viewers termed "chip extraction viewers" open, along with link boxes in each of the two main viewers showing the areas highlighted in the chip extraction viewers, and the GCP tool. You can

move and resize the chip extraction viewers, and you can vary their magnification by resizing the link boxes.

The thing that you will need to concentrate on is the GCP tool. You have two sets of GCPs: *input GCPs*, which are in the arbitrary coordinate system of the satellite image and are digitized in the viewer from which you started the GCP tool, and *reference GCPs*, which are the known reference coordinates of the points corresponding to the input GCPs. Again, the *input viewer* contains the data to be rectified – in this case your aerial photograph. The *reference viewer* contains the data with the known reference system – in this case the DLG.

Look at the icon bar on the GCP tool. The third icon from the left (it looks like a Σ playing jump rope) turns on the automatic transformation calculation mode. Verify that this is depressed; it is the default condition when you open the GCP tool. Any ERDAS Imagine image can have a set of GCPs associated with it. This set is stored in the data file along with the raster layers. If a GCP set exists for the top raster layer shown in the viewer, then those GCPs are shown when you bring up the GCP tool.

The CellArray of the GCP tool shows the locations of each GCP in both viewers. The first column shows the ID of each GCP. Each ID begins with the default ID string, GCP#. You can change this if you want (e.g. if you have more than one set of GCPs for a particular image).

The most appropriate GCPs to choose on a satellite image are easily visible phenomena such as road intersections, stream junctions, bridges over streams, etc. (That's why you have the DLGs for roads and streams as your references!).

To set up GCPs, find a place which you can easily make out on the images in both viewers. Click on the "Create GCP" icon (it looks like a circle with 4 tics on the inside). For your first GCP, click on the place you've chosen in Viewer #1 and then on the same place in Viewer #2. You will notice three things. First, both viewers show a cursor that looks like the Create GCP icon and the notation GCP #1. Second, the chip extraction viewers show the same icon and notations. Third, the coordinates of the GCP appear in the GCP tool. If the cursor and the notations aren't easily visible in any of the viewers, you can change the color by clicking on the color swatch for Input GCP or Reference GCP to change a single cursor, or on the "Color" column head for the particular set of GCPs and then on one of the selected color swatches, if you wish to change them all. The most appropriate color for TM image input GCP colors is most likely yellow; you can take your choice for reference GCP colors. Note also that if you click on the "Select" icon in the GCP tool icon bar, you can move a GCP to a better position – either in the main viewer or in the chip extraction viewer. Get used to doing this. It is often a very very useful thing to be able to do. Note also that there are two columns in the GCP tool labeled ">". This shows the active record. Normally, if you are digitizing a new GCP, the ">" should be in a blank record. If you are changing the location of a GCP, the ">" should be in the record that you are changing. Note also that if you change the color swatch in the active record, you will change it for all subsequent records as well.

Create two more GCPs by clicking on corresponding places in the two viewers. Verify, in the chip extraction viewers, that you are satisfied that the GCPs refer to the same places in the two viewers. *Make sure also that your first three GCPs are widely distributed across the area you are ultimately concerned with!* This is very important. In principle, 3 points are sufficient to define a surface to transform the satellite image to the UTM reference system (or any other reference system desired). The reason it's important to get your first three points widely separated is that doing so gives you the best chance to define a surface which will be close to the surface you will choose as your final definition of the transformation.

Now create a fourth GCP. When you choose a GCP in either viewer, Imagine will place a GCP cursor in the other viewer at the place defined by the surface calculated from the points digitized thus far. You can move the point to the correct location by dragging it by the mouse.

Make several more GCPs. You can add as many GCPs as you want, but in general the more the better. If you want to move a GCP, select it, and drag the cursor in the viewer with your mouse. If you want to

delete a GCP, select it, right-click in the "Point #" column, and select "Delete Selection."

You will notice that when you digitize the fourth GCP, a column opens in the GCP tool, telling you what the residual error is for each point. Another field opens in the GCP tool telling you the RMS error for the transformation. You want to insure that the total RMS error is within the tolerance range. National Map Standards calls for RMS error less than one half of the resolution of the input raster. Since the reference system for the TM image is pixels, you should try to get the RMS error below 0.5 if possible. Note that the residual error shown for each point is an indication of the contribution of that point to the total RMS error. If one point has an unusually high residual error, you should verify that the GCPs in the two images really do correspond to each other, and move one or the other until they do. Alternatively, you might delete the GCP altogether.

You may have noticed, when you first started to do this exercise, that the Polynomial Model Properties dialog had a field called "Polynomial Order" with a default value of 1. The polynomial order is an indicator of the mathematical order of the transformation surface. You can change the order, if you choose to do so, by going back to the Polynomial Model Properties dialog (available from the Geo Correction Tools dialog). The number of GCPs required to calculate the transformation is equal to $\frac{1}{2}(t+1)(t+2)$, where "t" is the order of the transformation. Thus, a first-order transformation matrix requires 3 points ($\frac{1}{2} * 2 * 3$); a second order transformation matrix requires 6 points ($\frac{1}{2} * 3 * 4$), etc. Once you have digitized enough GCPs to calculate the transformation surface, you are told your RMS – and you can transform the image if you choose to do so. Try changing the order of the transformation. What does it do to your RMS error?

Thus far, all of the GCPs you have digitized have been control points. That is, you digitize them in both viewers, and they are used to calculate the transformation surface. You can also digitize ground check points to check the accuracy of your transformation. First, change all of your GCPs to yellow by right-holding "Select All" in the Point # column and then right-holding "Yellow" in each of the two Color columns. Right-hold "Select None" in the Point # column of the GCP Tool CellArray to deselect the GCPs. In the last row of the CellArray, right-hold in each of the two Color columns and select "Magenta." All of the Ground Check points you add in the next steps will be magenta, so that you can tell them from the GCPs. Select the last row of the CellArray by clicking in the Point # column next to that row. Select Edit-Set Point Type-Check from the GCP Tool menu bar. Then select Edit-Point Matching from the GCP Tool menu bar. The GCP Matching dialog opens. One of the fields in the dialog is labeled "Correlation Threshold." Change it to 0.8, and press "Return." Click the "Discard Unmatched Point" checkbox to activate it. Then click Close to dismiss the GCP Matching dialog.

In the GCP Toolbar, click the "Create GCP" icon and then the Lock icon. Create at least 5 check points in each of the two viewers, just as you did for the GCPs. If your check points do not fall within the correlation threshold, they will go unmatched and be discarded. After you have input as many check points as you choose, unlock the "Create GCP" icon by clicking on the Lock icon. Click on the "Compute Error" icon on the GCP Tool icon bar (the check in the square) to compute the error for the check points. This is an RMS error for the check points, based on the transformation surface generated by your control points. If you wish to see your polynomial coefficients, click the Model Properties icon in the Geo Correction Tools dialog. When you are satisfied, click Close.

You are now ready to *resample* the image. Resampling is the process of calculating the file values for the rectified image and creating the new file, based on the new reference system and the pixel values of the original file. All of the raster data layers in the new source Viewer will be resampled, and the output image will have as many layers as the input image. Most GIS products support at least 3 resampling orders: nearest neighbor, bilinear interpolation, and cubic convolution. The three are very different, and you must be very clear on what you want. Nearest-neighbor resampling finds the pixel in the *original* image closest to each pixel in the *new* image, and assigns that pixel in the new image with the value of that pixel in the original image. Bilinear-interpolation resampling finds the 4 pixels in the original image closest to each pixel in the new image, and assigns that pixel in the new image with the average value of the 4 pixels in the original image. Cubic-convolution resampling finds the 16 pixels in the original image closest to each pixel in the new image (i.e. the four considered in bilinear interpolation plus the 12 pixels surrounding them), and assigns that pixel in the new image with the weighted average value of the 16 pixels in the

original image. Which you choose will depend on what you wish to do with the new image. The lower-order resampling preserves the actual digital numbers reported by the satellite; the higher-order resampling gives a smoother surface, where the spatial distribution of the digital numbers is least altered from the original.

To resample the image, click on the "Resample" icon in the Geo Correction Tools dialog. It's the one that looks like a skewed square with 4 quadrants. When the Resample dialog opens, choose an appropriate name for the output file, and choose the appropriate resample method. Verify that new map projection is what you expect. Verify the size of the output cell, and check to ignore zero is statistics.

You last piece of information for this dialog is the geographic boundaries of the new output file. For this operation, you can use the default values. Click OK to perform the resampling.

To verify that you've rectified the image correctly, add the new image in Viewer # 2. Using View-Arrange Layers in the Viewer menu bar, adjust the layers so that the DLGs are on top of the new image, and click on Apply. Do the DLGs line up correctly on the rectified aerial photograph? **You should include this image in your portfolio for this unit.**

Rectifying the Satellite Image of Your Quadrangle

In most respects, rectifying a TM image to correspond to the quadrangle you have been working with since Unit 6 is very straightforward and follows the process you used to rectify the aerial photograph. Your first step is to choose an satellite image. Our repository of these is also on the R: drive, which is arranged by path-row. Ohio is covered by 9 thematic mapper satellite scenes: paths 18 - 20 and rows 31 - 33. The Cleveland area is included in both Path 18/Row 31 (most of Cuyahoga county and east into Pennsylvania) and Path 19/Row 31 (most of Cuyahoga county and west past Toledo). The names of the images includes the date of acquisition as well as the path-row information.

Choose an appropriate image – i.e. one that looks interesting (or is from an interesting time of year) and load it into one of your open viewers. To help you locate yourself, find Lake Erie, Cleveland, Akron, Warren, and other cities and villages in the area. Larger reservoirs include Mosquito Creek (on Mosquito Creek), East Branch, LaDue, and Rockwell (on the Cuyahoga), Mogadore, West Branch, etc. Now find the portion of the image which corresponds to your quadrangle. Approximately what are the X and Y coordinates of the outside portions of your quadrangle?

Next, load the appropriate DLG files into your reference viewer. Note that the TM image appears already to have been registered to UTM projection: It has projection information, and the numbers that appear at the bottom of the viewer as you move the mouse around appear to be UTM coordinates. The reason for this is that we purchase this imagery from the USGS already rectified. We have found, however, that the rectification is not quite correct.

Follow the process you used above: click on "Raster ->Geometric correction" in the viewer containing the TM image, select polynomial correction, and identify the viewer containing your DLGs as the reference viewer. Add GCPs as you did with your aerial photograph, and complete the reregistration of the image. The process for registering a TM image is identical to that for registering an aerial photograph, although you will notice some differences in actually carrying out the job since the resolution of the TM image is much lower. We will need to discuss these differences in class.

There is one other major difference. The TM image you are using is an entire scene. You want to end up with a properly registered quadrangle. To crop the scene to your quadrangle, you will need to identify the corners of the image you wish to produce. The most appropriate corners to use are those of the DLGs of your quadrangle. To find them, use ImageInfo to determine the values of the X and Y coordinates of the Upper Left and Lower Right corners, respectively (ULX, ULY, LRX, and LRY). Put these numbers into the appropriate place in the final Resample dialog box.

To verify that you've rectified the image correctly, add the new image in Viewer # 2. Using View-Arrange

Layers in the Viewer menu bar, adjust the layers so that the DLGs are on top of the new image, and click on Apply. Do the DLGs line up correctly on the rectified satellite image? **You should include this image in your portfolio for this unit.**

Questions to Consider

1. You used a first-order polynomial transformation to convert your image to UTM. Do you think there might have been advantages to using a higher-order polynomial transformation?
2. Several different transformation algorithms are available in Imagine for image rectification. We used Polynomial because it is straightforward. Do you think that a different algorithm might have been more appropriate?
3. How useful would your image have been had you not transformed it to UTM (or some other standard reference system)?
4. How many layers does the TM image used in this rectification have? Which ones are you looking at? How many rows and columns does it have? What skip factor is being used? What does skip factor mean?
5. Can you imagine any way in which the image may have been clarified, so that you could see features more easily? How, for example, would you have used layers 1, 2, and 3, or 2, 5, and 7?

Portfolio

1. Your composite image of the rectified aerial photograph from downtown Cleveland with some DLGs on top of it, with each DLG having a suitable symbology.
2. Your composite image of the rectified satellite image for your quadrangle with some DLGs for that quadrangle on top of it, with each DLG having a suitable symbology.