GEOG 361 **Remote Sensing in Geosciences**

Lab Exercise 2 **Georeferencing and Co-registering An Aerial Photograph**

Over the years, this georeferencing lab has been built on work by Dr. Hongxing Liu and Dr. Andrew Klein

I. Introduction to Georeferencing

One of the most important, yet hardest to grasp, concepts in remote sensing and GIS is how to correctly **georeference** or **geocode**) a vector or raster coverage so that it can be viewed or analyzed along with other georeferenced information. This process is commonly known as coordinate **transformation** or **georeferencing**. While it is not absolutely to bring an image into a real-world coordinate system, sometime it is sufficient to simply align one image with another, though this has become less common in recent years.

Georeferencing is a process that transforms a spatial data set from an arbitrary image coordinate system into a geographic coordinate system. This process is also known as *warping, rubbersheeting, rectification, registration, co-registration*, or *ortho-rectification*. These terms may have slightly different meaning in different contexts.

Rectification is the process of using Ground Control Points (GCPs) to transform the geometry of an image so that each pixel corresponds to a position in a real world coordinate system (such as Latitude/Longitude or Eastings/Northings of UTM), in which the image is expanded or compressed and rotated as needed to align with a real world map grid or coordinate system.

Orthorectification is a more accurate form of rectification because its takes into account sensor (camera) and platform (aircraft or satellite) characteristics as well as terrain elevations.

Registration is simply aligning two images so that they can be overlaid or superimposed for comparison. In this case, the images do not have to be rectified to a map projection. They can both be in a "raw" coordinate system.

The key point to grasp about georeferencing or coordinate transformations is **the necessity to locate positions or features in a vector or raster coverage whose real world coordinates are known** (e.g. its latitude/longitude or x,y in a known map projection coordinate system such as UTM). The requisite georeferencing information can be collected in a number of ways.

1. Collect GPS points in the field of known locations (**ground control points or GCPs**) found on a map or in a remotely sensed image such as road intersections.
2. Use points of known latitude/longitude or other coordinates, such as a UTM grid, that printed on the map as **tie points.**
3. Use a previously georeferenced image as the basis for locating points on an unrectified map or remotely sensed image.

Once the relationship between the **tie points or GCPs**, which in a raster image may be their pixel locations or on a digitized map may be in 1/1000s of a centimeter from the origin on the digitizing tablets, and the locations of these tie points in the real world is established mathematically all points in the map, or pixels in the image, can transformed using the established equations.

II. The Co-registration Process

This lab is designed to build your skills in geo-referencing and co-registering a raw digital remote sensing image. Whenever accurate area, direction and distance measurements are required, raw image data must be processed to remove geometric errors and rectify the image to a real-world geographic coordinate system.

With aerial photograhs, which this lab focuses on, geometric errors may have been introduced by factors such as roll, pitch and yaw of the airplane platform. In order to overlay the raw image with other images or vector data layers, the raw image must be georeferenced and co-registered into the same coordinate system as that of other images and vector data layers. Georeferencing and co-registration can achieve two things: relate the image to a known map coordinate system when combining the image with other data, and correct geometric distortions to improve the accuracy when making measurements based on the image.

In this lab, you will use ENVI Registration function to perform an image-to-image rectification. Specific tasks for this lab include:

I. *Inspecting* a scanned high-resolution aerial photograph acquired over the Texas A&M campus and surrounding area and *identifying* a number of well-distributed Ground Control Points (GCPs) with reference to an geocoded Digital Orthorectified Quadrangle (DOQ);

II. Use ENVI to modify the GCP display and edit the GCPs;

III. Co-register the raw image to the datum and map projection of the DOQ using the polynomial transformation;

IV. Experiment with first and second order polynomial transform equations and observe the differences between the geocoded images;

V. Experiment with nearest neighbor, bilinear, and cubic convolution resampling techniques;

VI. Overlay the newly georeferenced image with the DOQ data in the RGB color mode to observe the changes in landscape;

VII. Display the census block group boundaries with the newly georeferenced aerial photograph as the image backdrop. In GIS lingo, a background satellite image or aerial photograph is sometimes referred to as *geographic wallpaper*.

The georeferencing and co-registration method that we are going to use is based on polynomial transform. It involves three major steps: identification of Ground Control Points (GCPs), selection of polynomial equations, and resampling.

As mentioned above, a set of **Ground Control Points** (GCPs) is required to establish the link between the arbitrary image coordinate system and geographical coordinate system. A ground control point (GCP) is a point on the earth's surface where both image coordinates (measured in rows and columns) and map coordinates (measured in degrees of latitude and longitude, meters, or feet) can be identified. The acquisition of Ground Control Points (GCPs) is a critical step for georeferencing and registering a raw image data set. The basic requirements for GCPs are that these points must be distinguishable both on the raw image and the georeferenced image. Road and stream intersections, building corners, bridges, rock outcrops, and other small, well-defined, permanent, visible features often meet the above requirements and serve as good candidate features for GCPs. The selected features should be small enough so that we can precisely pinpoint them at pixel level on the image. To achieve highly accurate georeferencing, the number of GCPs should be sufficient and the spatial distribution of GCPs should be fairly uniform across the entire area covered by the image. *The greater the variation in terrain and the greater the geometric distortion, the more GCPs are required.*

Using ENVI GCPs can be selected in a number of ways:

1) Selecting points from one or more other digital images which have already been geocoded,
2) Selecting points from vector based digital data, such as from a GIS or CAD vector overlay,
3) Using a digitizer to pick control points from a paper map, such as a USGS map, and
4) Typing in coordinates for known points, such as survey or GPS measurements

In this lab, GCPs will be selected using the first method – selecting them from a geocoded image.

Geometric Transformations

Based on the GCPs, a polynomial equation can be fitted and calibrated to complete the systematic geometric transformation of the raw image data from the arbitrary coordinate system to a known map projection coordinate system. The first order of the polynomial transform is also known as the affine transformation, which needs at least three GCPs. The general mathematical equations for Affine transformation are

$$x' = Ax + By + C \quad (1)$$

$$y' = Dx + Ey + F \quad (2)$$

The Affine transformation scales, skews, rotates, and translates the image coordinates of aerial photograph to match the DOQ image.

The second order polynomial is a quadratic equation. The higher the order of polynomial, the better the fit at the control points. This is at the cost of increasing inaccuracy and unpredictability away from the selected ground points, such as at the edges of image. It is typically best to use the lowest possible order of polynomial that gives an acceptable georeferencing error.

The **RMS** (Root Mean Square) **Error** is a standard statistical measure that attempts to describe the accuracy and consistency of the GCPs. It is calculated as the square root of the average square differences in the x and y locations between the actual GCP point location and the estimated GCP point location given by the fitted polynomial or affine equation. In order to estimate the warp coefficients (A,B,C,D,E and F in equations 1 and 2 above) using statistical methods, you must have at least four defined selected GCPs before there are enough degrees of freedom for an RMS error to be computed for each point.