Image Georeferencing and Rectification

Content
- Reasons for georeferencing and rectifications
- Geometric distortions
- Terrain distortions
- Ground Control Points
- Geocoding and orthorectification
- Image resampling method

Georeferencing and Rectification
- It is a process of transforming an uncorrected, raw image from an arbitrary coordinate system into a map projection (geographic) coordinate system. Namely, image pixels are positioned and rectified to align and fit into real-world map coordinates
- Geo-referencing is also known as geocoding, rectification, ortho-rectification, registration, coregistration, or geometric transformation in different contexts

Reasons for Georeferencing and Rectification
- Due to inherent geometric distortions, aerial and satellite images generally need to be geocoded before they can be used in geo-scientific analysis
- Data fusion: overlay a number of different images of the same area to combine their bands containing data into a single image dataset. The individual images must be georeferenced to a compatible coordinate system
- Comparing images for change detection
- Creating composite image maps
- Making measurements
- Mosaicking images

Geometric Distortions
- Any remote sensing image, regardless of whether it is acquired by a photographic system in an aircraft, a multispectral scanner on board a satellite, or any other platform/sensor combination, will have various geometric distortions

Sources of Geometric Distortions
- Imaging geometry of remote sensing systems
- Mechanical or optical imperfections of the sensor
- Earth rotation effects: rotation of the earth during image acquisition;
- The curvature of the earth surface;
- Atmospheric effects: bending of the light beams due to refraction;
- Motion and Insatiability of platform: variations in platform altitude, attitude and velocity;
- Topography effects: terrain relief distortion;
Geometric Distortions in Framing System
- Relief Displacement
- Perspective vs. Orthographic geometry
- Tilt Imaging Geometry
- Geometric Distortions in Along-track Scanning System
- Geometric Distortions in Across-track Scanning System
- Panoramic Distortions in Ground Resolution Cell Size
- Variation in Ground Resolution Cell Size
- Scanning System Tangential Scale Distortion

Correction of Geometric Distortions
- Geometric distortions are often systematic (predictable) and may be identified and corrected using pre-launch or in-flight platform ephemeris (i.e., information about the geometric characteristics of the sensor system and the Earth at the time of data acquisition) Geometric distortions in imagery can be corrected through analysis of sensor characteristics and ephemeris data. Three types of corrections
  - Rigorous orthorectification
  - Image-to-map rectification
  - Image-to-image coregistration

Orthorectification and orthoimages
Orthographic projection
- With the orthographic projection of a map, all features are located in their correct horizontal positions and are depicted as though they were each being viewed from directly overhead
- Only the base (or top) of an object can be seen and represented by a map (with orthographic projection)

Central (perspective) projection
Orthorectification
- Uncorrected aerial photographs are not maps. They are single-point perspective views of the Earth's surface, whereas maps are orthogonal representations of the surface

Rigorous Orthorectification Process
- Orthorectification corrects local and global distortions by modeling imaging geometry (the position and attitude of sensor or camera) and terrain topography. It is a more accurate form of rectification
- All georeferencing and rectification methods require selection of GCPs, although orthorectification process needs relatively fewer GCPs
- Orthorectification of Digital Aerial Photos
- The following information is required: 1) Pre-launch or in-flight space-borne platform ephemeris data (altitude, velocity, attitude at the time of data acquisition) 2) Sensor viewing geometry 2) Digital Elevation Model (DEM)
**Image-to-Map Rectification**
- This procedure is commonly used to rectify remotely sensed data to a standard map projection whereby it may be used in conjunction with other spatial information in a GIS to solve problems.

**Image-to-Image Co-registration**

**Ground Control Points**
- Ground control points are also known as tie points, tick points, conjugate points in other contexts.
- Candidate features for GCPs
  - Locations that can be easily and clearly identified and precisely located are good candidates to be chosen as control points.
  - Visible, small, stable, permanent, and well-defined landmarks.

**Ground Control Point (GCP) Acquisition**
- The distribution of tie points should be fairly uniform across your study area.
- The number of GCPs required depends on the terrain, the size of the image, and the rectification method and the order of mathematical equation utilized. The greater the terrain variations and geometric distortion, the more GCPs that are required.
- The geographic coordinates of ground control points are often determined from topographic map, ground survey, or GPS measurement.
- GCP Link File Format

<table>
<thead>
<tr>
<th>Point</th>
<th>Xi_image</th>
<th>Yi_image</th>
<th>Xi_state</th>
<th>Yi_state</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1655</td>
<td>2693</td>
<td>35537794799</td>
<td>102116525559</td>
</tr>
<tr>
<td>2</td>
<td>1500</td>
<td>2986</td>
<td>35525079185</td>
<td>102140797149</td>
</tr>
<tr>
<td>3</td>
<td>2152</td>
<td>2859</td>
<td>35578729998</td>
<td>102130937236</td>
</tr>
</tbody>
</table>

**Polynomial Method**
- The Polynomial method model distortions by fitting a polynomial mathematical function through Ground Control Points. It does not require knowledge of the sensor geometry or how the image was captured.
- A polynomial is essentially a mathematical equation which links the uncorrected raw image to the georeferenced database based on the input ground-control points.
- Rectification Type: Linear (Affine), Quadratic or cubic polynomial.
- Generally, for moderate distortions in a relatively small area of an image (e.g., a quarter of a Landsat TM scene), a first-order, six-parameter, affine (linear) transformation is sufficient to rectify the imagery to a geographic frame of reference.
- You should select at least twice as many points as the number required.

**Affine Transformations**
- The Affine transformation scales, skews, rotates, and translates all coordinates in the image using the same equation. Namely, this type of transformation can model...
six kinds of distortion in the remote sensor data, including: translation in x and y, scale changes in x and y, skew, and rotation. Keep parallel lines parallel, it does not perform ‘rubber sheeting’

Rubber Sheet Method
- Curvilinear Transformations-Rubber sheeting
- Higher order transformations in a non-uniform manner, which do not necessarily keep lines straight and parallel. Parallel lines become non-parallel, possibly curved
- Triangulation is a method for rubber sheeting
- Required to rectify complex distortions such as panoramic distortion

Triangulation Method
- Triangulation (Rubber sheeting) Method
- Only the areas bounded by the GCPs can be rectified by the triangulation method. The regions that fall outside the GCPs can be rectified by the polynomial method

Georeferencing Information
- Once the image has been geocoded, the georeferencing information is stored in the image header file (section)

Error of Georeferencing and Rectification
- A least squares fit method is used to fit the transformation parameters
- At least one ground control point more than the minimum required is needed to generate an RMS error
- Root Mean Squared Error is a statistical measure of the error between the calculated coordinates of a GCP from the fitted polynomial equation and the measured (true) coordinates of the GCP from GPS, topographic map, or a georeferenced image
- The polynomial will not transform every GCP with 100 per cent accuracy and it is important before the full rectification proceeds to ensure that the errors are within acceptable limits
- The RMS error value for each GCP affects and is affected by other GCPs

Outliers in GCPs
- Iterative selection of GCPs
- Not all of the original GCPs selected are used to compute the final six-parameter coefficients used to rectify the input image. An iterative process can be used to evaluate and select quality GCPs

Forward versus Inverse Transformation
Input-to-Output (Forward) transformation
- Forward mapping logic works well if we are rectifying the location of discrete coordinates found along a linear feature such as a road in a vector map

Output-to-Input (Inverse) Mapping
**Resampling Method**

- When georeferencing (geocoding) and rectification is performed, the output grid (image) will commonly have different cell (pixel) size, orientation, and coordinates from those in the input image. To determine the DN values for cells (pixels) in output grid (image), the resampling (intensity interpolation) process is required.

- Resampling is the process of determining new values for output pixels after geometric transformation of input image. It is based on the original image.

- The three resampling techniques commonly used: nearest neighbor assignment, bilinear interpolation, and cubic convolution.

- The nearest neighbor assignment will identify the location of the closest input cell, then assign the value of the nearest input cell to the output cell.

- Two linear interpolations are performed along the scan lines.

- Cubic convolution uses the 16 nearest input cells to determine the output cell value. A smooth cubic polynomials are fitted along the four lines of the four pixels surrounding the point in the image.

**Selection of Resampling Method**

- The nearest neighbor assignment
  - Closest value, Fast, Coarse
  - should be used for nominal (categorical) or ordinal data
- Bilinear interpolation
  - Smoothing, Faster
- Cubic convolution
  - Slow, very smooth, intermediate values, overshoots

**Suggested Reading**


Please see the class slides for the details.