Remote Sensing: Module 2

- Principles of geometric correction and resampling techniques.

Scan line offset of a satellite image

Earth rotation is a major source of geometric distortion in satellite imagery

Example Landsat: Across Track Sensor

Landsat MSS: 6 strips at the same time

End product

The scanning system determines the image’s geometry

Eventually in image analysis we want to have the imagery brought into a grid system so that we can overlay it on maps and process it in a GIS. However, the geometry of the raw imagery does not correspond to the geometry of a map, because of specific differences in the projection.

- In photographic systems: Central Projection:
  One image frame is taken at one time.
- In scanning systems: Mixed type of projection.

Recap: Effect of Central Projection

On the image, the tree is not “at the right place”, but “stretched” and displaced. We can use these specific distortions to measure tree height!

Recap: Effect of Central Projection (2)

- Terrain:
  Depending on terrain elevation:
  Scale varies over the image and objects are displaced and, depending on their vertical extension, distorted.

Source: Albertz 1991
Source: Lillesand & Kiefer 2001
The geometry of satellite raw images does not correspond to a map grid nor to a geographical grid. Major sources of geometric distortions include:

- Earth's rotation under the satellite during image acquisition,
- Earth's curvature,
- Panoramic effects (view angle),
- Topography,
- Gravitational anomalies causing speed and altitude changes in the satellite,
- Satellite platform instability.

Example

Example: Raw image  |  Corrected to UTM projection

Failure to correct geometric distortions ...

1. Can make area estimates almost worthless,
2.Precludes integration of imagery with other sources of map data,
3. Prevents two images of the same area taken at different dates from being compared pixel by pixel,
4. Can limit our ability to relate spectral features distinguishable in the image with landscape features on the ground.
There are different types/levels of geometric correction of remotely sensed imagery…

1. **Registration**: The alignment of one image to another image of the same area.
2. **Rectification**: The alignment of an image to a map so that the image is planimetric, just like the map. Also known as geo-referencing.
3. **Geocoding**: A special case of rectification that includes scaling to a uniform standard pixel GIS. The use of standard pixel sizes and coordinates permits convenient layering of images from different sensors and maps into a GIS.
4. **Orthorectification**: Correction of the image, pixel by pixel for topographic distortion. The result is that every pixel appears to be viewing the earth from directly above, i.e. the image is in a strict orthographic projection.

Two general strategies for geometric correction

1. **Modelling** the nature and magnitude of all sources of geometric distortion and find the corresponding correction formulae.
   - This approach works well when all sources of distortion are well understood and can be quantified.
   - This is not the case for all sources of distortion, particularly not for the unsystematic variations in satellite altitude etc.
2. **"Empirical" approach**, using reference points (ground control points=GCPs).
   - The model required for geometric correction is then built from the positional differences between reference points and their location in the imagery.
   - This approach does not require knowing either the source or the magnitude of the errors.
   - It is, therefore, the more frequently applied approach.

Identification of ground control points which are then used to do the transformation of pixel coordinates
Types of ground control points

1. x- and y-coordinate known.
   Geo-referencing / Image rectification requires information about 2-dimensional position.

1. x-, y- and z-coordinate known.
   Orthorectification requires information on the 3-dimensional position of the GCPs (x-, y- and z-coordinate known).

Geometric correction goes in two steps

1. Transformation of pixel coordinates = removing the geometric distortions.
   Because the raw image was distorted, it is not possible to overlay the raw image onto the corrected image such that each pixel in the corrected image is covered by a single pixel from the raw image, therefore:

2. Brightness values (gray values) must be assigned to each pixel of the corrected image (=resampling). This is done by interpolation of the corresponding neighborhood pixels in the raw image.

1st step: transformation of pixel coordinates

- Bring each point of the raw image to its geometrically correct position in the final image.
- As we do not have information for each point, we search for the true positions of pixels (instead of points). 

Quelle: Albertz 1991
**1st step: transformation of pixel coordinates**

- To transform pixel locations in the distorted image (row \( r \) and column \( c \)) to true map coordinates \((x, y)\) we need to develop two transformation functions: \( r = a(x, y) \) and \( c = b(x, y) \).

(The empty output map is cell by cell filled with the corresponding information from the distorted image). I.e. we search for each cell at \((x, y)\) the corresponding pixel values at \((r, c)\).
- The transformation functions are not known, they are "empirically" built using statistical modelling techniques.
- The positions of ground control points (GCP) are determined in the reference map and in the uncorrected image.
- From those data-pairs, the transformation functions are derived which are usually simple, first-, second, or third-order polynomials. Example for first-order polynomials:
  
  \[
  r = a_0 + a_1x + a_2y \quad \text{and} \quad c = b_0 + b_1x + b_2y
  \]

**Illustration of transformation of pixel coordinates**

[Diagram: Illustration of transformation of pixel coordinates (Source: Wilkie & Finn 1991)]

**Principles for the selection of ground control points**

1. High contrast in all images of interest.
2. Small feature size.
3. Unchanging over time.
4. All are at about the same elevation (unless topographic relief is being specifically addressed).

Man made features prove the most reliable for GCPs.

Examples of typical GCPs:
- Road intersection, bridges.
- Corners of agricultural fields.
- Small islands or river features (constancy over time to be verified).
Assessment of accuracy of geometric correction

1. After having established the correction model (the regression functions, we can check with the GCPs how well the fit is.

2. However, in general it is not a good practice to verify the quality of a model fit using the same data points that were used for model building. The model can be perfect at those data points – but bad in other locations. An independent set of points should be available.

3. Therefore, two distinct sets of GCPs may be collected - one for building the model, - one for assessing the goodness of fit of the model.

2nd step: brightness value interpolation

- When the geometrically corrected position of the pixels is found, we need to assign new brightness values to the new pixels, as usually a new pixel does not match exactly one original pixel.

- Different strategies for brightness interpolation from surrounding pixels:
  1. Nearest neighbor (1): retaining an original BV
  2. Bilinear (4) smoothing
  3. Cubic convolution (16)