

MODULE – 3 LECTURE NOTES – 2

GROUND CONTROL POINTS AND CO-REGISTRATION

1. Introduction

Remotely sensed images obtained raw from the satellites contain errors in the form of systematic and non systematic geometric errors. Some of the errors can be rectified by having additional information about satellite ephemeris, sensor characteristics etc. Some of these can be corrected by using ground control points (GCP). These are well defined points on the surface of the earth whose coordinates can be estimated easily on a map as well as on the image.

2. Properties of GCP

For geometric rectification of image from a map or from another registered image, selection of GCP is the prime step. Hence, proper caution must be maintained while choosing the points. Some of the properties which the GCP should possess is outlined below:

- a. They should represent a prominent feature which is not likely to change for a long duration of time. For example, the choice of a highway intersection or corner of a steel bridge is more appropriate as a GCP than a tree or meandering part of a river. This is essential for easiness in identifying points from the image/map as permanent locations will not perish for a long duration of time.
- b. GCPs should be well distributed. This means that rather than concentrating on points lying close to each other, points selected farther apart should be given priority. This enables the selected points to be fully representative of the area, as it is essential for proper geometric registration. More knowledge about this step will be reiterated in section 3 and 4.
- c. Optimum number of GCPs should be selected depending on the area to be represented. Greater the number of carefully selected and well apart points, more will be the accuracy of registration.

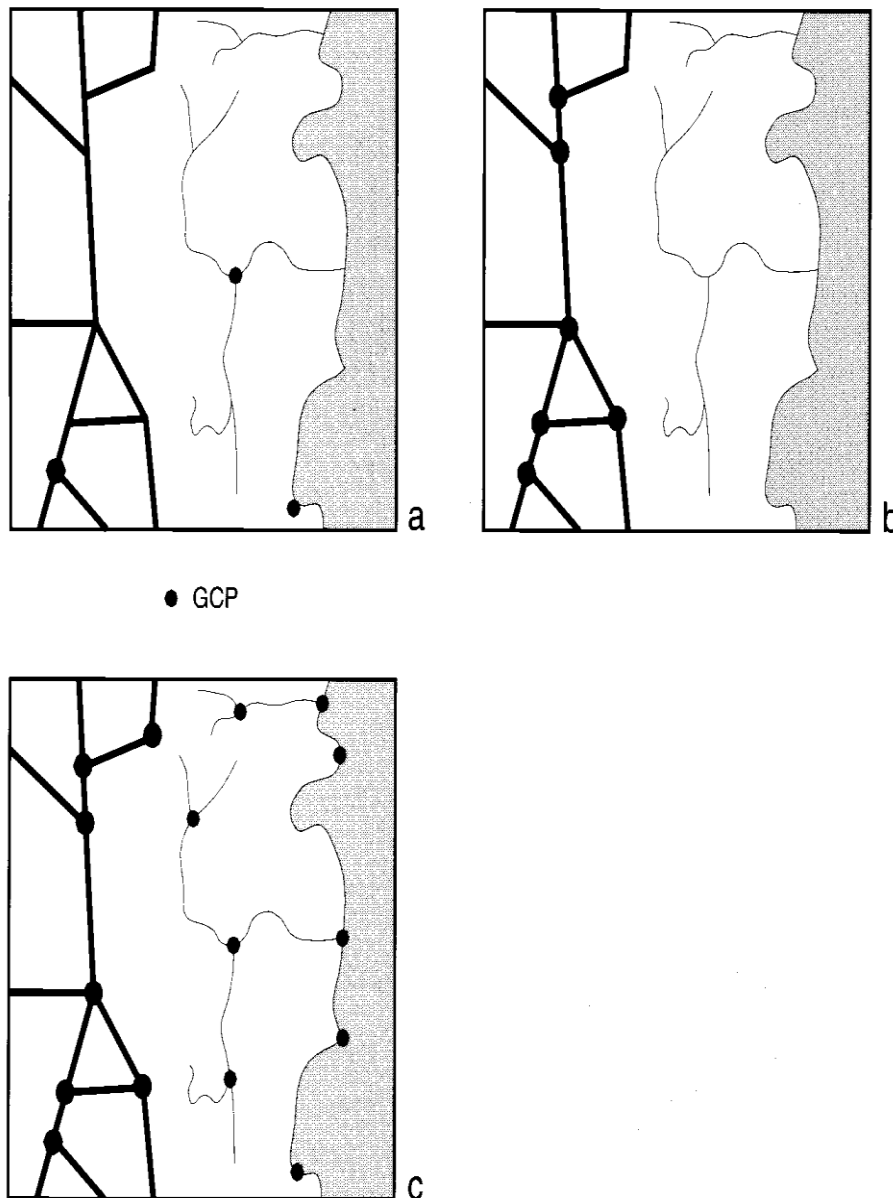


Figure 1. (a) Insufficient distribution of GCP (b) Poor distribution of GCP (c) Well distributed GCP

The GCP when selected from a map leads to image to map rectification whereas that chosen from an image results in image to image rectification.

3. Geometric rectification

This process enables affixing projection details of a map/image onto an image to make the image planimetric in nature. The image to be rectified, represented by means of pixels arranged in rows and columns can be considered equivalent to a matrix of digital number (DN) values accessed by means of their row and column numbers (R,C). Similarly, the map/image (correct) coordinates of a same point can be represented by their geolocation information (X,Y). The nature of relationship of (R, C) with (X, Y) needs to be established so that each pixel in the image be properly positioned in the rectified output image. Let F_1 and F_2 be the coordinate transformation functions used to interrelate the geometrically correct coordinates and distorted image coordinates. Let (R, C) = distorted image coordinates and (X,Y) = correct map coordinates

Then $R = F_1(X, Y)$ and $C = F_2(X, Y)$

The concepts is similar to affixing an empty array of geometrically correct cells over the original distorted cells of unrectified image and then fill in the values of each empty cell using the values of the distorted image. Usually, the transformation functions used are polynomial. The unrectified image is tied down to a map or a rectified image using a selected number of GCPs and then the polynomials are calculated. The unrectified image is then transformed using the polynomial equations.

To illustrate this method, let us assume that a sample of x and y values are available wherein x and y are any two variables of interest such as the row number of an image pixel and the easting coordinate of the same point on the corresponding map. The method of least squares enables the estimation of values of x given the corresponding value of y using a function of the form:

$$x_i = a_0 + a_1 y_i + e$$

Here, as only a single predictor variable of y is used, the expression is termed as univariate least squares equation. The number of predictor variables can be greater than one. It should be noted that a first order function can only accomplish scaling, rotation, shearing and reflection but they will not account for warping effects. A higher order function can

efficiently model such distortions though in practice, polynomials of order greater than three are rarely used for medium resolution satellite imagery.

3.1 Co-Registration

Errors generated due to satellite attitude variations like roll, pitch and yaw will generally be unsystematic in nature that are removed best by identifying GCPs in the original imagery and on the reference map followed by mathematical modeling of the geometric distortion present. Rectification of image to map requires that the polynomial equations are fit to the GCP data using least squares criteria in order to model the corrections directly in the image domain without identifying the source of distortion. Depending on the image distortion, the order of polynomial equations, degree of topographic relief displacement etc will vary. In general, for moderate distortions in a relatively small area of an image, a first order, six parameter affine transformations is sufficient in order to rectify the imagery. This is capable of modeling six kinds of distortion in the remote sensor data which if combined into a single expression becomes:

$$\begin{aligned}x' &= a_0 + a_1x + a_2y \\ y' &= b_0 + b_1x + b_2y\end{aligned}$$

Here, (x, y) denotes the position in output rectified image or map and (x', y') denotes the corresponding positions in the original input image.

3.2 Image Resampling

Resampling is the process used to estimate the pixel value (DN) used to fill the empty grid cell from the original distorted image. A number of techniques are available for resampling like nearest neighbor, bilinear, cubic etc. In nearest neighbor resampling technique, the DN for empty grid is assigned to the nearest pixel of the overlapping undistorted correct image. This offers computational simplicity and alteration of original DN values. However it suffers from the disadvantage of offsetting pixel values spatially causing a rather disjointed appearance to the rectified image. The bilinear interpolation technique considers a weighted average approach with the nearest four pixel values/DN. As this process is actually a 2D equivalent of linear interpolation, hence the name 'bilinear'. The resulting image will look smoother at the stake of alteration of original DN values. Cubic interpolation is an improved

version of bilinear resampling technique, where the 16 pixels surrounding a particular pixel are analyzed to come out with a synthetic DN. Cubic resampling also tends to distort the resampled image. In image processing studies, where the DN stands to represent the spectral radiance emanating from the region encompassing field of view of sensor, alteration of DN values may result in problems in spectral pattern analysis studies. This is the main reason why image classification techniques are performed before image resampling.

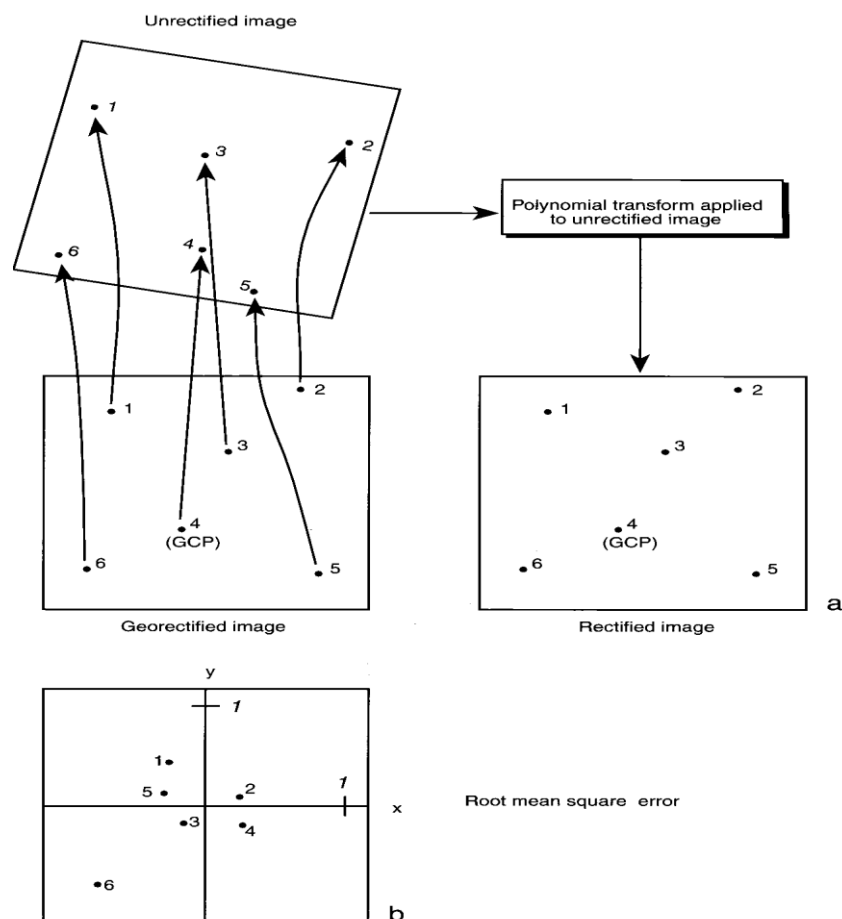


Figure 1: Polynomial transformation for geometric correction of images

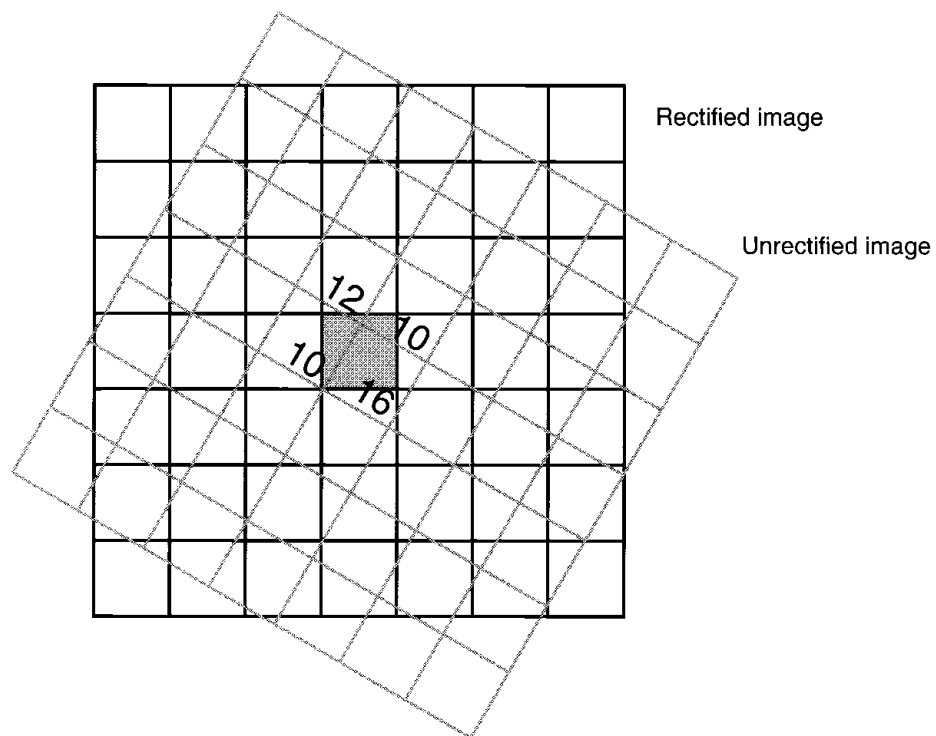


Figure 2: Image Resampling by overlay of rectified empty matrix over unrectified image.