Digital Image Processing
Image Restoration

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Digital Image Processing

- Image processing involves substituting the digital number (DN) associated with a particular pixel with another DN in order to enhance a particular feature

- Image Restoration (Pre-processing)
- Image Enhancement
- Information Extraction

(in the same order)

Digital Images

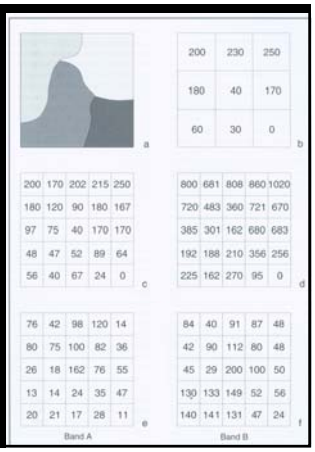
(a) Simple image and its corresponding digital numbers for

(b) Low spatial resolution 8-bit system

(c) High spatial resolution 8-bit system

(d) High spatial resolution 10-bit system and

(e)&(f) High spatial resolution, 8-bit, two-band system



Histogram

DN bin	Number of pixels
65	3,616
66	5,288
67	1,829
68	15,162
69	20,652
70	15,874
71	14,007
72	12,716
73	1,819
74	1,836
75	7,466

DN bin	Number of pixels
76	11,655
77	7,522
78	5,118
79	2,600
80	2,004
81	2,617
82	870
83	1,094
84	719
85	792

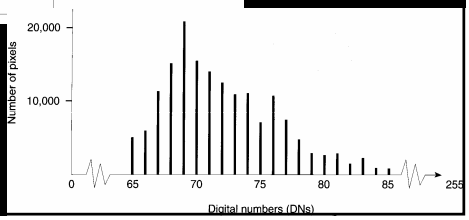
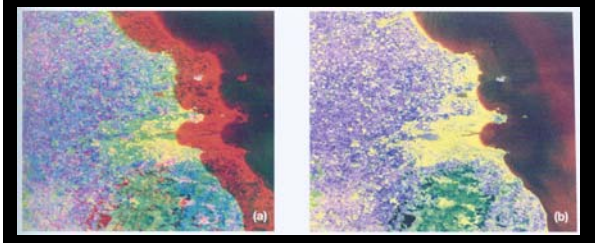


Image Restoration

- Co-registration of Data
- Line banding corrections
- Line dropout corrections
- Geometric corrections
- Atmospheric corrections
- Solar illumination corrections

Co-registration of Data

- In a MSS data set (n-bands) each pixel (on land) has n DNs
- All these n-bands should be co-registered to each other

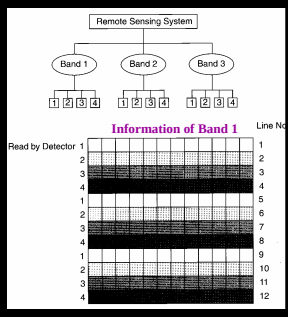


False colour MSS image showing offset of band 1 which is projected in red

Corrected false colour image in which the three bands are co-registered

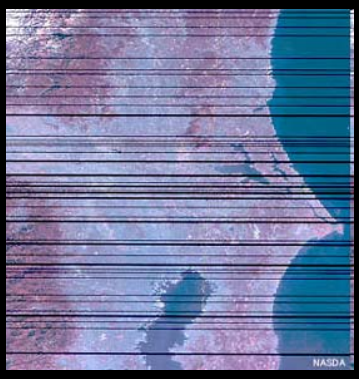
Line Banding Corrections

- Transverse scanning systems – Multiple Detectors
- Life of individual detectors



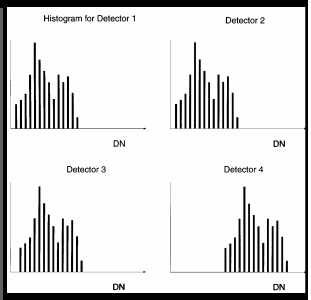
Sequence of lines read by detectors in in Transverse scanning system

Line Banding in Landsat-5 TM Image



Line Banding Corrections

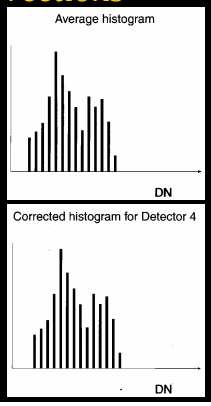
- A histogram for each detector in each band is produced.
- For a four detector system, histogram 1 is formed from data in lines 1, 5, 9 ... etc., histogram 2 from lines 2, 6, 10 ..., histogram 3 from lines 3,7, 11 ... and histogram 4 from lines 4, 8, 12 ...etc.
- Assuming each detector has sensed a representative sample of all the surface classes within the scene, each of the histograms will be similar (i.e. have the same mean and standard deviation) if the detectors are matched and calibrated.
- However, if one detector is no longer producing data readings consistent with the other detectors, its histogram will be different. Detector 4 in the figure is producing higher digital numbers than the other detectors.



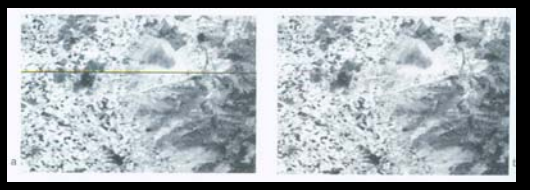
Histogram for each detector of Band 1 (say)

Line Banding Corrections

- An average histogram is produced by using the digital number from all the detectors (excepting the defective detector)
- The DNs produced by all the detectors are altered so that their histograms are then made to match the average one.
- When this procedure is completed, the imbalance between the detectors is eliminated and the image is said to have been de-striped.
- This procedure changes the DN for all lines, though the relative change for the properly functioning detectors is less when compared to systems having more detectors.
- A defective detector on the Landsat MSS forms one-sixth of the input to the average histogram whereas a defective detector for a reflected TM band contributes only one-sixteenth of the input to the average histogram.



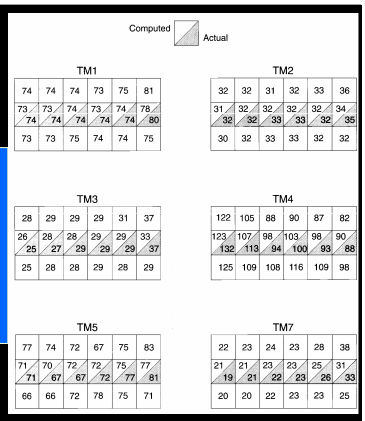
Line dropout corrections



Line dropout corrections

Comparison of actual and computed line dropout values.

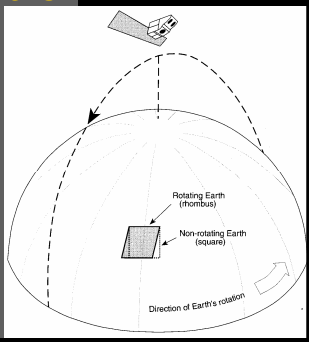
Taking the average of the line above and below shows little divergence from the actual vales for most bands



Geometric Distortions

- Systematic Distortions
  - Predictable & apply to all images from the platform
- Non-systematic Distortions
  - Applicable to individual images

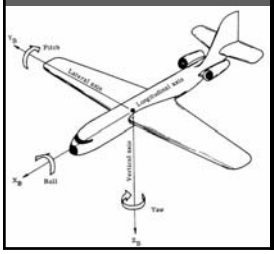
- Systematic Distortions
  - Due to earth's rotation
    - 28 sec for one image in Landsat MSS
    - An average histogram is produced by using the digital number from all the detectors
  - Velocity variations in scanning mirror
  - Near polar orbit (9º from true polar)
  - Can be corrected from the accurate monitoring of satellite orbital path
  - Normally corrected before the data are delivered

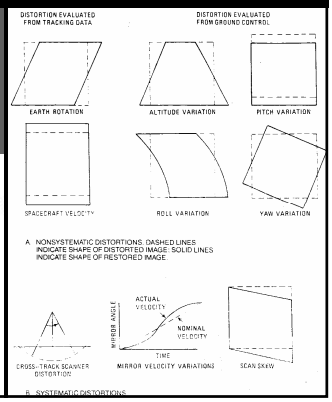


Distortion due to earth's rotation

Geometric Distortions

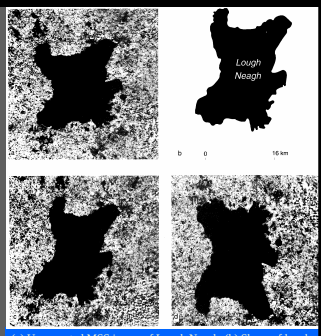
- Systematic Distortions
- Non-systematic Distortions
  - Small variations in the satellite's orbit
  - Attitude of the satellite
    - Pitching, Rolling and Yawning
- Landsat data





Geometric Corrections

- Ground Control Points (GCPs)
  - A point whose position can be determined on the uncorrected image (row and column) and also on the geo-referenced data set or image (latitude, longitude or grid coordinates)
  - GCP collection
  - Polynomial Transformation



(a) Uncorrected MSS image of Lough Neagh. (b) Shape of lough from 1:250,000 topographic map. (c) Geometrically rectified MSS image of Lough Neagh. (d) Error in rectification process.

Polynomial Transformation

$$x_u = a_0 + a_1x + a_2y$$

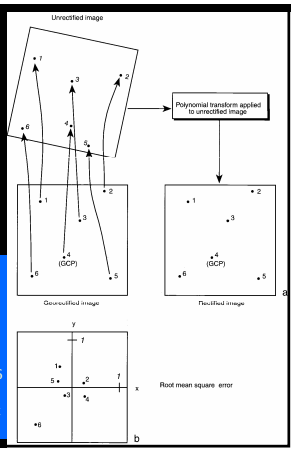
$$y_u = b_0 + b_1x + b_2y$$

$$x_u = c_0 + c_1x + c_2y + c_3xy + c_4x^2 + c_5y^2$$

$$y_u = d_0 + d_1x + d_2y + d_3xy + d_4x^2 + d_5y^2$$

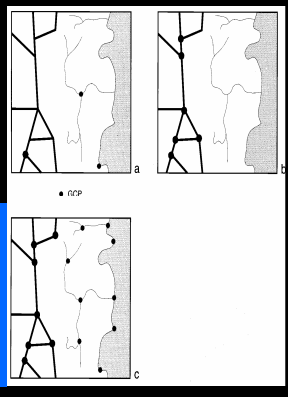
(a) Rectification process. Unrectified image is tied down to a map or rectified image and the polynomials calculated. The unrectified image is then transformed using the polynomial equations,

(b) Graphical expression of root mean square error. In this instance ground-control point 6 appears to be in error, possibly due to an inaccurate tie-down or the input of incorrect co-ordinates



GCP Collection

- Choice of GCPs
  - Number of GCPs
  - Distribution in the image



(a) Insufficient ground control points to yield a good rectification

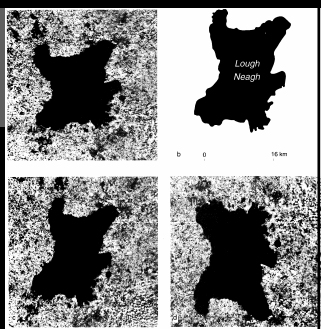
(b) Poor distribution of ground control points to yield a good rectification

(c) Good rectification because of use of large number of evenly distributed ground control points

Geometric Corrections

(c) Geometrically rectified MSS image of Lough Neagh

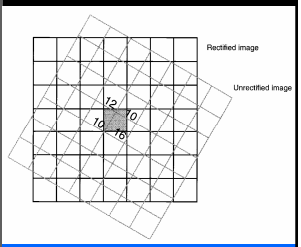
(d) Error in rectification process



(a) Uncorrected MSS image of Lough Neagh. (b) Shape of lough from 1:250,000 topographic map. (c) Geometrically rectified MSS image of Lough Neagh. (d) Error in rectification process.

Geometric Corrections

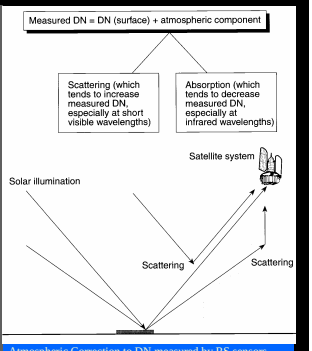
- Shaded pixel is assigned a value of 16.
- A bilinear interpolation produces a new DN that is the weighted average of the four closest pixels. With this transform the new DN for the shaded pixel would be 12, assuming each pixel is given equal weight.
- Computing time for a bilinear interpolation is greater than for a nearest-neighbour interpolation and image resolution is not as good because of the smoothing effect of this method.
- Cubic convolution employs a weighted average of the closest 16 pixels, which further increases the computing time.



Resampling of Digital Numbers for Rectified Image

Atmospheric Corrections

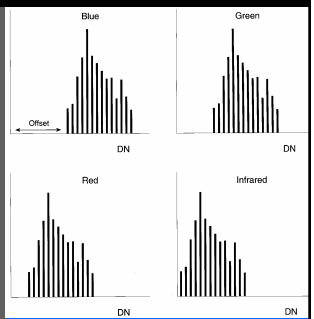
- When a detector on a remote sensing system measures the radiance of a pixel and assigns it a DN, the DN is formed of two components
  - One is the actual radiance of the pixel which we wish to record, but added to it is an atmospheric component.
  - The atmospheric component has a scattering effect which tends to increase the DN that is assigned to the pixel and also an absorption effect which may reduce the assigned DN.



Atmospheric Correction to DN measured by RS sensors

Atmospheric Corrections – contd..

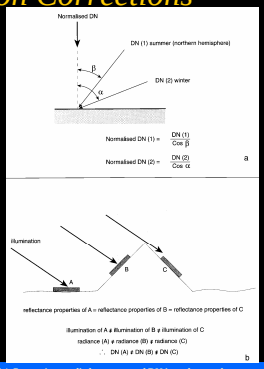
- The extent to which the atmosphere alters the true DN is best seen by an examination of the DN histograms for different bands.
- Many scenes contain very dark pixels (such as those in deep shadow) and it might be assumed that they should have a DN of zero. However, when the histograms for different bands are examined, some are seen to be offset from zero.
- Scattering is inversely proportional to wavelength. Thus shorter wavelength bands have a greater offset from the origin
- The degree of offset is dependent on the atmospheric conditions that change laterally and temporally. It is therefore not possible to give absolute offsets which are applicable in all situations.
- For Landsat TM, typical offsets are of the order of TM 1: 25-35; TM 2: 20-30; TM 3: 10-20; TM 4:5-15; TM 5: 0-5; TM 6: 0-5; TM 7: 0-5.
- A first-order atmospheric correction may be applied to remotely sensed datasets by assuming the offsets are due solely to atmospheric effects and subtracting the offset from each DN (not correct always)



DN offsets in DN histograms resulting from atmospheric scattering.
Offsets tend to be greater for lower wavelengths bands.

Solar Illumination Corrections

- Images obtained at different times of the year are acquired under different illumination conditions
- Solar illumination angle, as measured from the horizontal, is greater in the summer than in the winter
- In change detection images, if two images of the same area, taken on different dates, are compared, they will not be similar even if there has been no change in the spectral characteristics of the elements within the scene because of the different illumination angles
- In order to ascertain whether any changes have occurred in a region, it is necessary to remove the effects of the differing solar illumination. One method of doing this is to normalize the data by calculating for each pixel (based on the actual DN) the DN that a pixel would be expected to have at a particular illumination angle



(a) Correction applied to measured DN in order to take account of different illumination angles
(b) Effect of varying aspect with respect to illumination on the measured DN