# 7 DIGITAL IMAGE PROCESSING AND ANALYSIS

## *Introduction*

Digital image data are usually the remotely sensed data, and as such, the data processing in remote sensing is referred as *digital image processing* (DIP). The DIP consists in the application of algorithms on digital images to process, analyse and extract information of interest by manipulation and interpretation of the images. The digital image processing is usually done using raster data structure—each image is treated as an array of values. Since it is easy to find and locate pixels and their values, these can be manipulated easily by image processing system. Although, there are many possible forms of digital image manipulation image rectification (preprocessing), image enhancement, image transformation and image classification are some of the common features. After the completion of the preprocessing, the analyst may use feature extraction* to reduce the dimensionality of the data. Steps involved in digital image processing are presented in Fig. 7.1.

The raw data received from the imaging sensors, on the satellite platforms, contain flaws and deficiencies and, therefore, needs processing, to get the originality of the data. The steps involved may vary from image to image depending on the type of image format, initial condition of the image, composition of the image, and the information of interest. The image analyst examines the images to identify objects and judge their significance through feature extraction, segmentation and classification.

By studying the remotely sensed data, the analyst logically detects, identifies, classifies, measures and evaluates the significance of the objects, their patterns and spatial distributions. The ultimate aim of DIP is to extract information from a digital image that is not readily apparent or available in its original form. For effective DIP the data must be originally recorded digital data, stored in digital data storage device (e.g., hard disc, CD, DVD, etc.), and a computer, referred to as an image analysis system, with necessary hardware and software to process the data. The scope of the book does not permit to get into the complex mathematics involved in digital image processing. However, principles behind the process are explained for in-depth understanding. *Feature extraction* is the process of isolating the most useful components of the data, discarding the errors, for the further study. It reduces the number of variables to be examined thereby saving time and resources. In a multispectral data, the feature extraction helps to portray

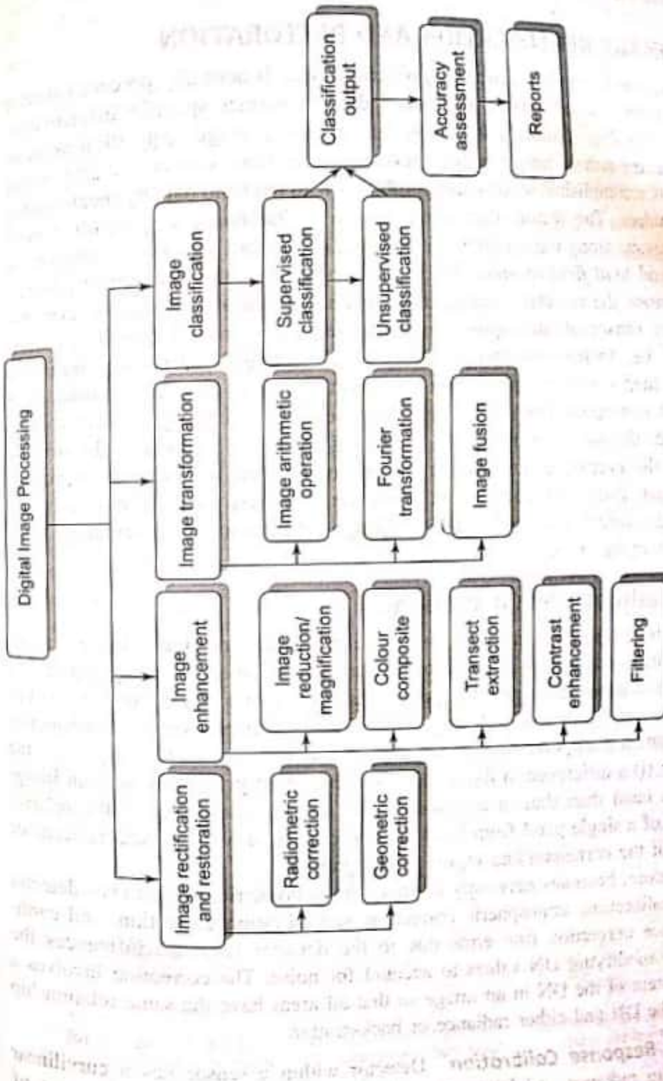


**Fig. 7.1** *Steps involved in digital image processing*

the necessary elements of the image by enhancing the statistical characteristics of image data such as individual bands or combination of band values that carry information concerning systematic variation within the scene; feature extraction should not be got confused with the geographical features visible on the image. Once the feature extraction is over the analyst can work with the image comprising of desired channels or bands.

## 7.1 IMAGE RECTIFICATION AND RESTORATION

This operation is often termed as *preprocessing* since it normally precedes further manipulation and analysis of the image data to extract specific information. Distortions or degradations in the image stem from the image acquisition process. Therefore, the aim of image rectification and restoration is to correct the image data and is accomplished by offsetting problems with the band data by recalculating the DN values. The factors that affect are the *digital image acquisition type*—digital camera, along-track scanner, across-track scanner; *platform*—airborne vs. satellite; and *total field of view*. The preprocessing operation attempts to correct or compensate the remotely sensed data for errors such as *radiometric errors*—removal of sensor or atmospheric noise to represent ground conditions more accurately, i.e., to improve image fidelity by correcting for data loss, removing haze; and then *geometric distortions*—converting data to ground coordinates by removal of distortions from sensor geometry, enabling mapping relative to data layers. Once the errors are removed, the data is said to be *restored* to its original condition; the correct values are never known. Further, the attempt to correct the data may itself introduce errors. However, all these corrections might not be required in every case and will depend upon the nature of information to be extracted from the data.

### 7.1.1 Radiometric Corrections

When the image data contains errors in the measured brightness values of the pixels, it limits the ability of the analyst to visually interpret or quantitatively process and analyse the images. The potential sources of errors are: periodic drift or malfunctioning of a detector; electronic interference between sensor components; and intermittent disruptions in data transmission and recording. Consequently, the affects are: (i) a difference in the relative distribution of brightness over an image in a given band than that in a ground scene and (ii) distortion of the relative brightness of a single pixel from band to band compared with spectral reflectance character of the corresponding region of the ground.

It, therefore, becomes necessary to apply the radiometric corrections—detector response calibration, atmospheric correction, sun elevation correction, and earth-sun distance correction (the error due to the detector response influences the most)—by modifying DN values to account for noise. The correction involves a rearrangement of the DN in an image so that all areas have the same relationship between the DN and either radiance or back-scatter.

***Detector Response Calibration*** Detector within a sensor has a curvilinear response to radiance and backscatter. Radiance is measure of the amount of EM radiation leaving or arriving at a point on surface, whereas backscatter is reflection of signals back to the direction from which they came. If the form of detector response is known, it can be used to transform the detector output from a curvilinear to a linear response (Fig. 7.2). Further, since the original detector responses are measured in laboratory and do change with time, even after the application of correction the response remains slightly curvilinear and may require further treatment. This is known as *nominal correction*. The detector response calibration consists of noise correction, de-striping, and line-drop outs. This is known as *supplemental correction*.



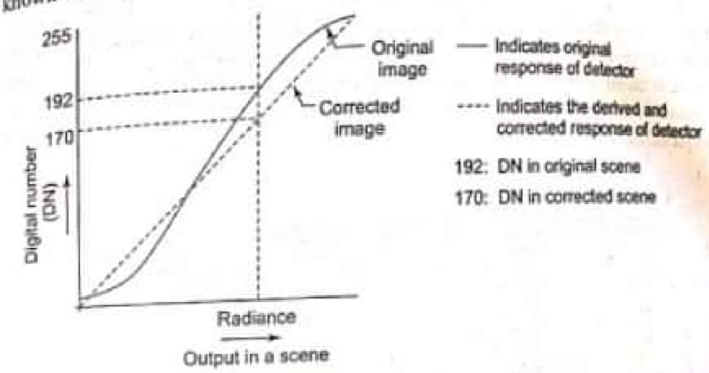


Fig. 7.2 *Radiometric correction*

1. *Noise correction:* Any unwanted disturbance in image data that is due to limitations in the sensing, signal digitisation, or data recording process is known as *image noise*. Noise can either degrade or totally mask the true radiometric information content of a digital image. Noise can be systematic (periodic), or random, or a combination of both. When odd pixels have a marked difference in their DN from those of adjacent pixels in the affected band, they are classed as *random noise*. The random noise problem is characterised by non-systematic variations in grey levels from pixel to pixel called *bit errors*. The noise values normally change much more abruptly than true image values. Pixel with spurious DN can be replaced with the average value of the neighbouring DNs. Moving neighbourhoods or windows of 3 × 3 or 5 × 5 pixels are typically used in such procedures (Fig. 7.3).




Fig. 7.3 *Moving window concept*

2. ***De-striping:*** When a detector goes out of adjustment, *de-striping*, also known as *line striping* or *banding* (Fig. 7.4), occurs. The error is due to periodic drift or malfunctioning of a detector. This was a common problem in early Landsat MSS data due to different drifts with time of the six MSS detectors resulting in different brightness by each detector. A systematic horizontal banding pattern on images produced by electro-mechanical scanners result in a repeated pattern of lines with consistently high or low DNs. Striping may also occur due to improper data recording and transmission.

The de-striping process consists in constructing histograms of the problem band for each detector and calculating the mean and standard deviation for each histogram. In case, if these statistical parameters come out to be different, they are made equal to the mean and standard deviation value of the whole image. Application of the de-striping correction enhances the visual appearance and interpretability of the image.

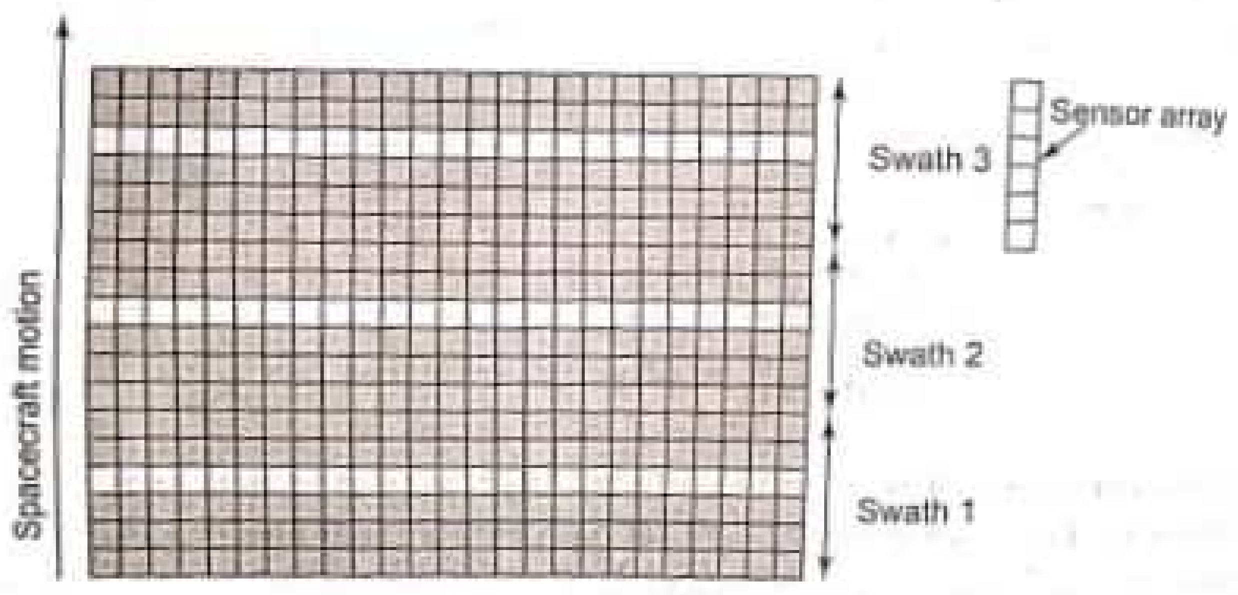


**Fig. 7.4** *De-striping (line striping)*

Some detectors generate noise which is a function of the relative gain/offset differences of the detectors within a band which results in banding. Such errors can be corrected using a histogram based approach. For example, a histogram for each detector in each band can be produced. Assuming that 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, even if one detector is no longer producing data readings consistent with the other detectors, its histogram will be different. An average histogram can be generated by using the DN values from all the detectors except the faulty detector. The DN produced by all the detectors get 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 the 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 contributed only one –sixteenth of the input to the average histogram. Fig. 2 show the histograms of each detector that tries to visually depict the line banding effect in detector 4. Fig. 3 shows the corrected histogram for the faulty detector 4.

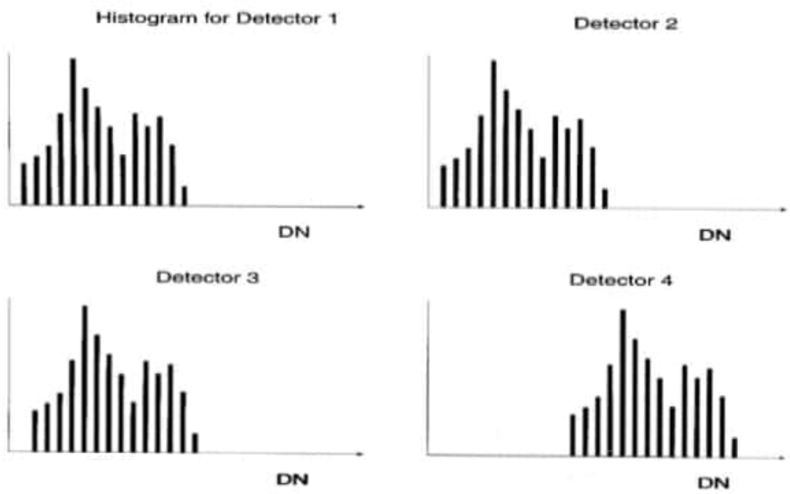


**Figure 2: Histogram of each detector of a hypothetical band**

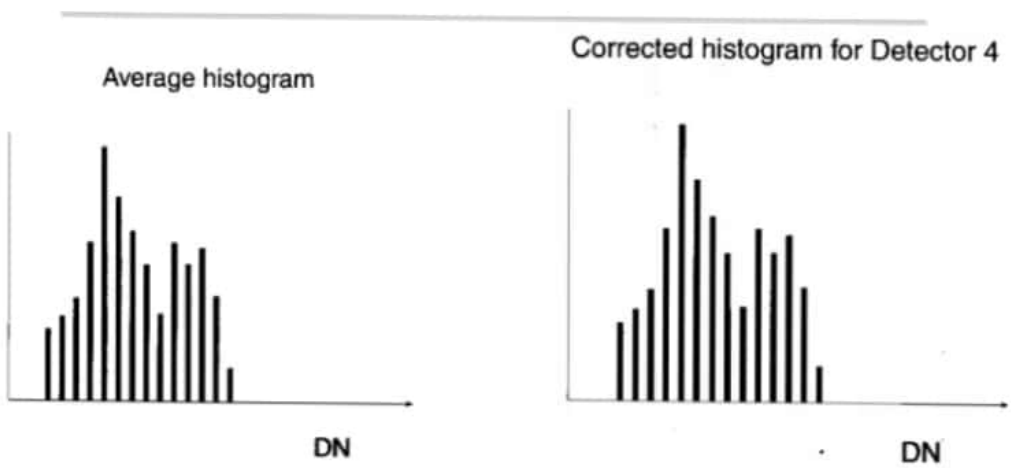


**Figure 3: Line banding corrections**

3. *Line-drop outs:* When a detector malfunctions completely or temporarily, a string of adjacent pixels in a scan line may contain defective data (spurious DN value) creating a horizontal streak, or miss a partial or complete line. The correction process consists in replacing the drop-out line (if only one line) by the average of the immediate preceding and next neighbouring lines. In case of two lost lines, the first lost line is replaced by the preceding line and the second lost line by the subsequent line. When three lines are lost, the outer two lines are treated as above and the middle line is recovered by averaging the two outer recovered lines. Recovery of three lost lines is the limit of the correction to be affected. Line-drop outs are also an example of systematic noise.

This error results in transverse scanning systems when out of the multiple detectors used, 1 or 2 fails to function properly. Satellites like Landsat MSS has 6 detectors of which sometimes even if one detector fails to function properly, this results in zero DN recorded for every pixel during corresponding scan lines. Such images will be smeared with black lines.

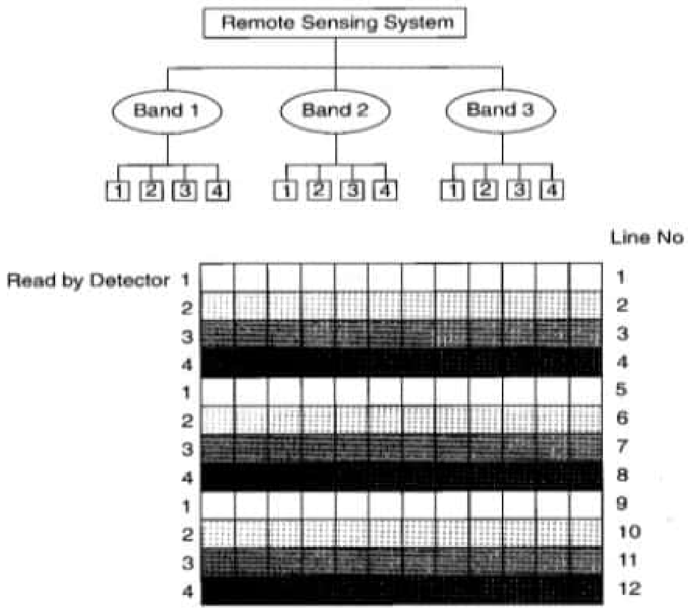


**Figure 1: Sequence of lines read by detectors in Transverse scanning system**

There is no exact methodology to restore the DN values of such images. However, to improve the interpretability of such images, sometimes average of preceding and succeeding lines of DN are used as corrected DN values. The justification of this procedure stems from the geographical continuity of terrain.

### Atmospheric Corrections

The DN measured or registered by a sensor is composed of two components. One is the actual radiance of the pixel which we wish to record, another is the atmospheric component. The magnitude of radiance leaving ground is attenuated by atmospheric absorption and the directional properties are altered due to scattering. Other sources of errors are due to the varying illumination geometry dependent on sun's azimuth and elevation angles, ground terrain. As the atmosphere properties vary from time to time, it becomes highly essential to correct the radiance values for atmospheric effects. But due to the highly dynamic and complex atmospheric system, it is practically not possible to understand fully the interactions between atmospheric system and electromagnetic radiation. Fig. 4 shows schematically the DN measured by a remote sensing sensor.

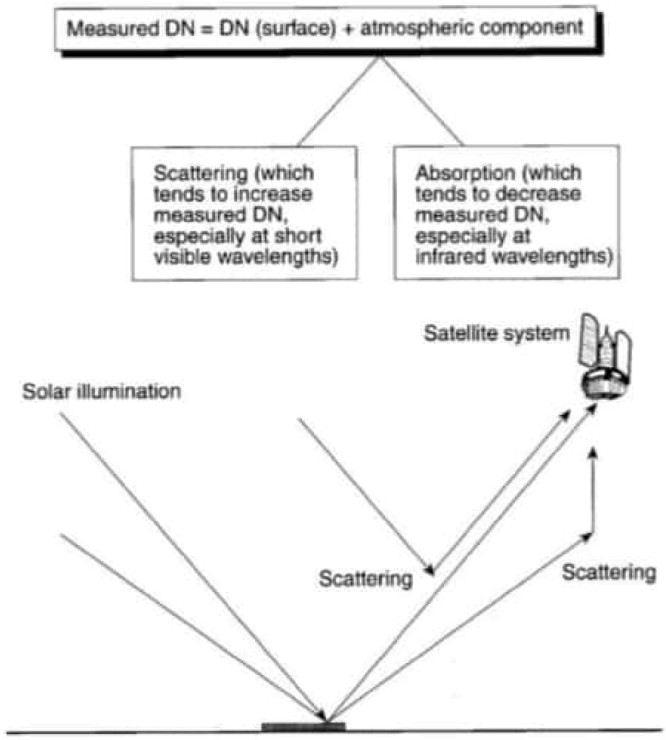


**Figure 4: Atmospheric correction to DN measured by remote sensing sensors**

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***Sun Elevation Correction*** The correction accounts for the seasonal position of the sun relative to the earth. The image data acquired under different solar illumination angles are normalised by calculating pixel brightness values assuming the sun was at the zenith on each date of sensing. The correction is applied by dividing each pixel value in a scene by the sine of the solar elevation angle for the particular timing and location of imaging (Fig. 7.5).

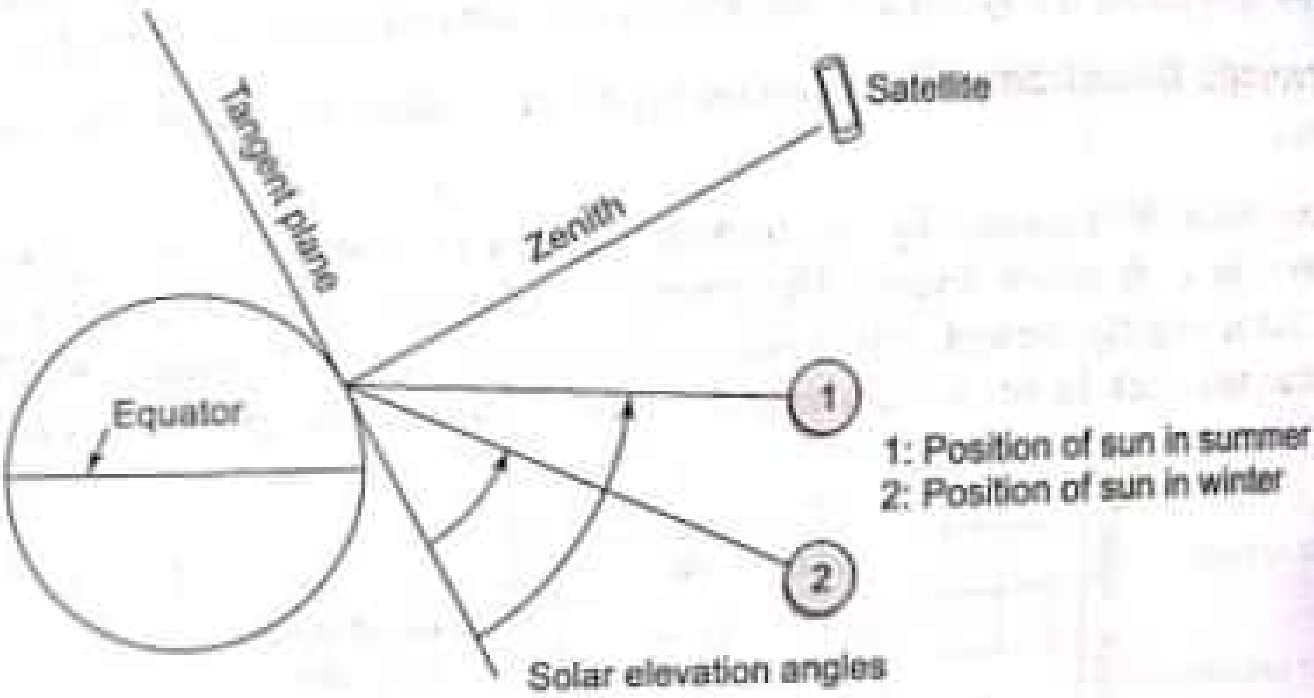


**Fig. 7.5** *Effects of seasonal change on solar elevation angle*

***Earth-Sun Distance Correction*** The correction is applied to normalise for the seasonal changes in the distance between the earth and the sun. The irradiance from the sun decreases as the square of the earth-sun distance. Neglecting the atmospheric effects, the combined influence of solar zenith angle and earth-sun distance on the irradiance incident on the surface of the earth can be expressed as

$$E = \frac{E' \cos\theta}{d^2}$$

where

$E$ = normalised solar irrediance

$E'$ = solar irradiance at mean earth-sun distance

$\theta$ = angle of sun from zenith

$d$ = earth-sun distance, in astronomical units

**Note** *The solar elevation angle and the earth-sun distance for a given scene are ancillary data supplied with the digital data.*