3. *Cubic convolution method:* This method is also known as bi-cubic convolution or second-order interpolation method. It is supposed to be the most sophisticated and complex method of resampling. It uses a weighted average of values within a neighbourhood of (4 × 4) 16 adjacent input pixels. Though, the images produced are noticeably sharper than the previous two methods, but get drastically altered. This method, however, introduces some loss of high frequency information.

7.2 IMAGE ENHANCEMENT

Even after applying the radiometric corrections an image might not be visually interpretable and may require further treatment to enhance the image. The process consists in converting the image quality to a better understandable level for feature extraction or subsequent visual image interpretation; increasing the visual distinctions between the features in a scene is known as *image enhancement*. Thus, the main object of image enhancement is to make the satellite images more informative and suitable for a specific application. This goal can be achieved by *point application*, also referred to as *radiometric enhancement*—changing the values of individual pixels independent of the other pixels; and *local operations*, also referred to as *spectral enhancement*—changing the value of individual pixels with regards to the neighbouring pixel values. The image enhancing techniques are applied either to single-band image, or separately to the individual bands of a multiband image set, and are accordingly classed as *spectral enhancement techniques* and *multi-spectral enhancement techniques*. There are numerous image enhancement techniques, some of the most important are the image reduction, image enlargement, colour compositing, transect extraction, contrast enhancement, and digital filtering. These are described briefly as follows.

7.2.1 Image Reduction

Since the display monitor generally consists of 1024 × 768 screen resolution only, the computer display systems are unable to feature a full image at the normal image pixel scale (e.g., higher than 2500 rows and 2500 columns). Now, since the entire image cannot be viewed, location of exact coordinates of the area of interest (AOI) may not be possible. In such a case the original image data set is reduced to a smaller data set, and the analyst can view the AOI at one time on the screen by deleting systematically selected rows and columns. To accomplish this, n^{th} row and n^{th} column of the image may be selected and displayed, where n may be suitably chosen say 2, 3, 4,.. etc. With a smaller n value, e.g., 2, there is a reduction of 25% pixels in the scene and it might not be enough to view the AOI defeating the effort. While a very large value of n, e.g., 10, will cause the image to retain only 1 % of the data, small enough to view the entire scene on the screen, but will not retain enough data for processing and interpretation. Therefore, a judicial selection of n value is an important key of the technique. Figure 7.13 shows an example of image reduction with n = 2.

42	52	75	81	60	52
30	54	72	32	44	76
41	64	71	45	85	63
44	85	72	55	81	78
91	62	86	72	54	46
72	60	23	42	81	73

(a) Raw image

42	75	60
41	71	85
91	86	54

(b) Reduced image

Fig. 7.13 *Image reduction*

7.2.2 Image Magnification

The process is also known as *zooming*. It is used to modify the scale of the image to improve the visual interpretation and to match the scale of another image. To accomplish this, an image is magnified by replication of rows and columns. For example, by using an integer factor $n = 2$ each pixel in the original image is replaced by $n \times n$ block of pixels as shown in Fig. 7.14; this will double the pixel size value. This technique is very useful when spectral reflectance or emitance of a very small area is of interest. Figure 7.14 shows an example of image enhancement with $n = 2$.

42	75	60
41	71	85
91	86	54

(a) Raw image

42	42	75	75	60	60
42	42	75	75	60	60
41	41	71	71	85	85
41	41	71	71	85	85
91	91	86	86	54	54
91	91	86	86	54	54

(b) Magnified image

Fig. 7.14 *Image magnification*

7.2.3 Colour Compositing

Coloured images can be interpreted better than the black and white images. Images are usually coloured by pseudocolour on single images and normal or false colour on several images as discussed in Section 6.10.3 (Chapter 6). The Pseudocolour involves replacement of each grey level in the image with a colour which separates the small grey scale differences that can not be distinguished by normal human eye.

Digital images are typically displayed as additive colour composite using the three primary colours red, green and blue denoted as RGB. The RGB colour cube (Fig. 7.15) is defined by the brightness level of each of the three primary colours. For a display with 8-bit-per-pixel data encoding (a common sample format), the range of possible DNs column component is 0 to 255. Hence, there are 256^3 (16,777,216) possible combinations of primary colours. The line from origin of the cube to the opposite corner is known as *grey line*, since DNs which lie on the line have equal components of primary colours. In DIP the RGB displays are used extensively to display normal colour, false colour infrared, and arbitrary colour composites. The procedure consists in contrast stretching and compositing the images and then colouring each waveband with a primary colour.

Colour compositing is a very useful technique to enhance visual interpretation. Combinations other than true colour combination produce false colour combinations resulting in identification of the features that were not visible in true colour composites. It is so because reflectance value of an object differs from band to band. For example, invisible infrared band is visible by obtaining red colour tones highlighting some invisible features.

For digital data three values corresponding to red, green and blue make various colour combinations. As an example, for a multispectral image of six bands, the number of colour composites that can be obtained in a combination of these would be

$$\frac{6!}{(6-3)!} = \frac{6!}{3!} = \frac{1\times2\times3\times4\times5\times6}{1\times2\times3} = 120$$

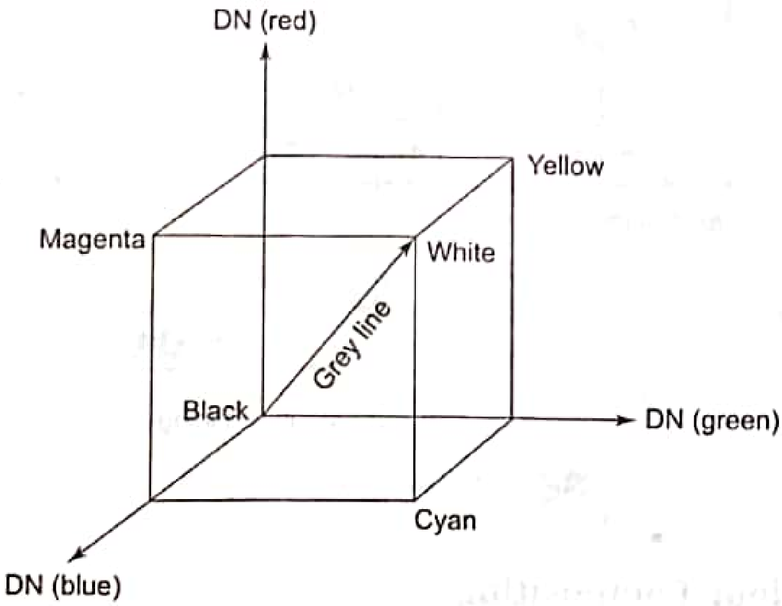


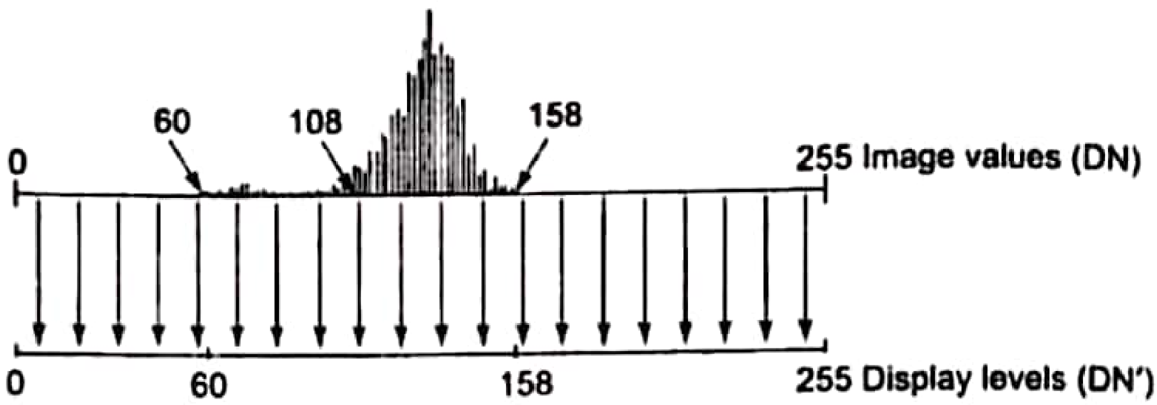
Fig. 7.15 *The RGB colour cube*

7.3 CONTRAST ENHANCEMENT

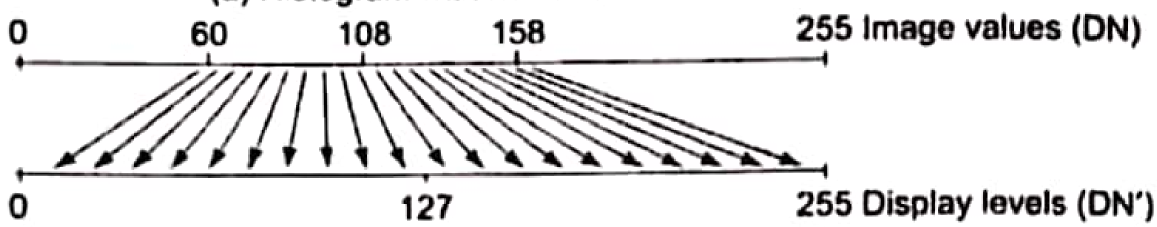
This is also referred to as *contrast manipulation*, or *radiometric enhancement*. In a raw image the useful data often populates only a small portion of the available range of digital values (e.g., 8 bits or 256 levels). Materials on the earth's surface reflect and emit different levels of energy. A sensor might record a considerable amount of energy from any material in a certain wavelength, whereas another material is recorded at a much less energy on the same wavelength. The ranges of brightness values present on an image are referred as *contrast*.

Contrast enhancement is a process that makes the image features more clearly by making optimal use of the colours available on the display or output device. It involves changing the range of values in an image in order to increase the contrast. For example, an image having a range of brightness value between 35 and 80 when stretched to a range of 0 to 255 enhances the differences between the features. the two techniques (the linear technique and the non-linear technique) for enhancing the contrast of an image, will be pertinent to discuss the key element of the enhancement techniques, the ***histogram***.

Histogram is a graphical representation of brightness values that comprises an image. It may also be defined as a statistical graphic representation of an image of tones from dark to light and associated number of pixels for each tone of an image (Fig. 7.16(a)). For a single band of data, the histogram contains the numbers of all possible brightness values along their horizontal axis and the associated number of pixel values along the vertical axis. A broad histogram reflects a scene with significant contrast, while a narrow histogram may appear dull or flat. Contrast as defined above is measure of the differences between light and dark areas in a scene.



(a) Histogram with no stretch



7.5 IMAGE TRANSFORMATION

This involves manipulation of multiple bands of data from image(s) of the same area acquired at different times (multitemporal image data), or from images of the same area acquired at different spatial resolution (multiresolution). The aim is to generate new images from two or more sources so as to highlight particular features or properties of interest better than the original input images. There are various methods of image transformation, e.g., image arithmetic operation, Fourier transformation, image fusion, etc. The image arithmetic operations are described as follows. The others involve complex mathematical techniques and are beyond the scope of this book.

Image Arithmetic Operations The operations of addition, subtraction, multiplication, and division are performed on two or more co-registered images of the same geographic area. These images may be separate spectral bands from a single multispectral data set or they may be individual bands from image data sets collected at different dates.

1. *Image addition:* For multiple, co-registered images of a given region for the same time and date of imaging, the new DN values of a pixel in the output image can be determined by averaging the DN values of corresponding pixels of input images (Fig. 7.21(a)). Image averaging finds application in the field of astronomy where low light levels cause sensor noise rendering poor image quality.

2. *Image subtraction:* This operation is carried out on co-registered scenes of the same area acquired at different times or dates, for change detection. This involves simple subtraction operation on the pixel values of the two images which have been geometrically registered (Fig. 7.21(b)). Image subtraction finds application in medical imaging called *mask mode radiography*.

3. *Image multiplication:* This operation is performed rarely. The best use of the method is made when an image of interest is composed of many distinctive regions, but the analyst is interested in any one region only (Fig. 7. 21(c)).

4. *Band ratioing:* This technique is also known as *spectral ratioing*. By division of DN values of one spectral band by corresponding DN value of another band, the resultant image enhances variations in the shapes of the spectral reflectance curves between the two different spectral ranges that may otherwise be masked by the pixel brightness in each of the bands. A major advantage of ratio images is that they convey the spectral or colour characteristics of image features, regardless of variations in scene illumination conditions. Hence, a ratioed image of the scene effectively compensates for the brightness variation caused by the varying topography and emphasises the colour content of the data. This is the most common arithmetic operation used in geological, ecological, and agricultural applications.

7	11	51	16
54	48	32	21
52	70	22	43
58	62	60	33

+

51	60	21	62
43	62	63	73
32	24	32	60
60	88	21	49

=

29	36	36	39
49	55	58	47
42	47	27	52
59	75	41	41

Example: 1st Pixel (7 + 51)/2 = 29
(a) Image addition

22	25	24	26
23	26	27	28
26	27	29	25
28	30	26	28

−

27	26	23	22
23	25	28	29
26	30	29	23
28	26	22	27

=

-6	-1	1	4
0	1	-1	-1
0	-3	0	2
0	4	4	1

Example: 1st Pixel 22 − 27 = 5
(b) Image subtraction

7	8	5	7
5	6	8	7
3	7	6	5
2	4	3	5

×

7	8	5	7
5	6	8	7
3	7	6	5
2	4	3	5

=

49	64	25	49
25	36	64	49
9	49	36	25
4	16	9	25

Example: 1st Pixel 7 × 7 = 49
(c) Image multiplication

Fig. 7.21 *Image arithmetic operations*

7.6 IMAGE CLASSIFICATION

A major task after feature extraction is to classify the object into one of several categories. Classification of remotely sensed data is achieved by assigning levels with respect to groups with homogeneous characteristics so that multiple objects in a scene can be discriminated. The level is called *class*. Classification may, therefore, be defined as the process of assigning the pixels in an image into a finite number of individual classes based on their DN values. The classification is usually based on the patterns of their DN, spatial relationship with neighbouring pixels, and relationships between data acquired on different dates. The term *pattern* is not geometric in character; rather it refers to the set of radiance measurements obtained in the various wavelength bands for each pixel. The objectives of image classification are to detect different kinds of features in an image, discriminate the distinctive shapes and patterns, and to identify temporal changes in the image. Classification transforms the image data into information. Classification is considered as the most important technique to extract information from the digital images.

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