UNIT 10 CHARACTERISTICS OF DIGITAL REMOTE SENSING IMAGES

Structure

10.1 INTRODUCTION

In Unit 7, you have studied about the concept of visual image interpretation with examples in Unit 8 of MGY-002. Now you have learnt that information derived from visual mode of image interpretation is mostly qualitative. In Unit 9, you have studied that the ground truth data acts as a link between the image and image derived information and the ground reality.

Computers handle data in digital form hence remote sensing data should be in digital form. In this unit, you will be introduced to the digital image, its characteristics and processing. Computer processing of a digital remote sensing data include several steps such as pre-processing, enhancement, transformation and information extraction. You shall also briefly learn about these steps prior to studying them in detail in subsequent Block 4 of MGY-002.

Objectives

After studying this unit, you should be able to:

- define a digital image and discuss its characteristics;
- list the components of an image processing system;
- discuss advantages of digital image processing;

- identify the steps in digital image processing;
- describe the concept of true and false colour composites; and
- define image histogram and discuss its importance.

10.2 DIGITAL IMAGE PROCESSING

Digital image and digital image processing have now become a part of our everyday life. Pictures taken on any digital camera or mobile device are the most common examples of digital images. Medical diagnostics is one of the fields where digital image processing has seen many developments such as bone scanning, digital X-Ray, MRI (Magnetic Resonance Imaging), digital mammograms. There are other fields where digital image processing techniques have enhanced extraction of information significantly and in a quantitative manner. Interest in digital image processing stems mainly from two application areas:

- improvement of pictorial information for human interpretations and
- processing of image data for storage, transmission and representation for machine perception.

Let us first study about image, digital image and advantages of digital image processing.

10.2.1 What is an Image?

In a broad sense, an ***image*** is a picture or photograph. They are most common and convenient means of storing, conveying and transmitting information. They concisely convey information about positions, sizes and inter-relationships between objects and portray spatial information that we can recognise as objects.

An image is usually a summary of the information in the object it represents. The information of an image is presented in tones and colours. In a strict sense, photographs are images, which are recorded on photographic film and have been converted into paper form by some chemical processing of the film whereas an image is any pictorial representation of information. So, it can be said that all photographs are images but not all images are photographs.

Mathematically, an image may be defined as a two-dimensional function $f(x,y)$, where x and y are spatial (plane) coordinates. The amplitude of f at any pair of coordinates (x,y) (or in other words, any location in the image) is called the *intensity* or *gray level* of the image and is proportional to the brightness of the scene at that coordinate/location (x,y).

10.2.2 What is a Digital Image?

When a paper photograph is scanned through a scanner and stored in a computer, it becomes a ***digital image*** as it has been converted into digital mode. When you see a paper photograph and its digital version in a computer, you do not see any difference. In digital mode, photographic information is stored as an array of discrete numbers. Each number corresponds to a discrete dot, i.e. one image element in an image. This *image element* is the smallest part of an image and is generally known as *picture element* or *pixel* or *pel*.

These numbers vary from place to place within the image depending upon the tonal variation. Number of pixels in an image depends upon the image size (length and width of the image). In any image, bright areas are represented by higher values whereas dark areas are represented by lower values. The values are known as ***digital number.***

We know now that a digital image is composed of a finite number of pixels, each of which has a particular location and value. In other words, when (*x*,*y*) and amplitude values of '*f*' are all finite, discrete quantities both in spatial coordinates and in brightness, the image is called a ***digital image***.

An image must be converted to numerical form before processing and this conversion process is called ***digitisation***. In Fig. 10.1, the image is divided into horizontal lines made up of adjacent pixels. At each pixel location, the image brightness is sampled and quantised. This step generates an integer at each pixel representing the brightness or darkness of the image at that point and is represented by a two-dimensional integer array and digitised brightness value is called *gray level*. Thus, it is a digital representation in the form of rows and columns, where each number in the array represents the relative value of the parameter at that point or over the unit area. Fig. 10.1 shows a digital image with its corresponding digital values. Here, if you notice you will observe that when the colour is dark the value of pixel is less and when the colour is light value is high. Similarly, Fig. 10.2 shows an image of size 4 × 4, where the value of *f*(*x*,*y*), say for (1,4), i.e. first row and fourth column, the corresponding value of pixel is 24.

14	13	2	24
7	30	11	11
25	22	15	8
10	5	28	26

Pixel

Fig. 10.1: A digital image (left) and its corresponding values (centre). Note the variation in the brightness and the change in the corresponding digital numbers. Highlighted block in the centre figure shows one pixel. The figure at right shows the range of values corresponding to the brightness

Column →

Row ↓	1	2	3	4
1	14	13	2	24
2	7	30	11	11
3	25	22	15	8
4	10	5	28	26

(1,1)	(1,2)	(1,3)	(1,4)
(2,1)	(2,2)	(2,3)	(2,4)
(3,1)	(3,2)	(3,3)	(3,4)
(4,1)	(4,2)	(4,3)	(4,4)

Fig. 10.2: Arrangement of rows and columns of an image of size 4 × 4 (4 rows and 4 columns). Left figure shows the numerical values in the image and the table at right shows the representation of pixel location for an image of size 4 × 4. You can observe that at location (1, 4), i.e. row 1 and column 4, the pixel value is 24

10.2.3 What is Digital Image Processing?

Interpretation of a digital image involves analysis of the image and extraction of information through computer software. Digital image analysis requires processing of the image using computer software. Those processing steps are called digital image processing. ***Digital image processing*** can be defined as subjecting numerical representation of objects (i.e. a digital image) to a series of operations in order to obtain a desired result. Digital image processing begins with one image and produces a modified version of that image. Digital image analysis is a process that takes a digital image into something other than a digital image, such as a set of measurements of the objects present in the image. However, the term digital image processing is loosely used to cover both processing and analysis.

10.2.4 Advantages of Digital Image Processing

There are certain thresholds beyond which the human interpreter cannot detect minor differences in image features in an image. For example, if a data is recorded with 256 gray shades, there may be more subtle information present in the image than we can extract visually. Similarly, it becomes difficult to keep track of a great amount of detailed quantitative information such as the spectral characteristics for crop identification purposes throughout a growing season. However, computer is much more adept at storing and manipulating such information.

Recall Table 7.1 of Unit 7 of course MGY-002 for comparison of visual and digital image interpretation.

Advantages of handling remote sensing data in digital mode as compared to photographic mode are listed below:

- ease in data storage and distribution
- images can be identically duplicated during reproduction and distribution without any change or loss of information
- visualisation of greater details
- images can be processed to generate new images without altering the original image
- faster extraction of quantitative information and
- repeatability of results.

Computer assisted image interpretation approach mimics the visual image interpretation approach to a certain level. Manual image analysis uses most of the elements of image interpretation such as tone, colour, size, shape, texture, pattern, height, shadow, site and association whereas computer assisted image interpretation involves the use of only a few of the basic elements of image interpretation. In fact, majority of all digital image analysis appears to be dependent primarily on just the tone or colour of image feature but both manual and digital analysis of remotely sensed data seeks to detect and identify important phenomena in the scene as both the interpretation approaches have the same general goals.

10.2.5 Components of an Image Processing System

The components of an image processing system differs depending on the different types of image, for example, satellite images and X-ray images cannot be processed by same type of image processing system. However, following components are the minimum requirement of an image processing system as shown in Fig. 10.3.

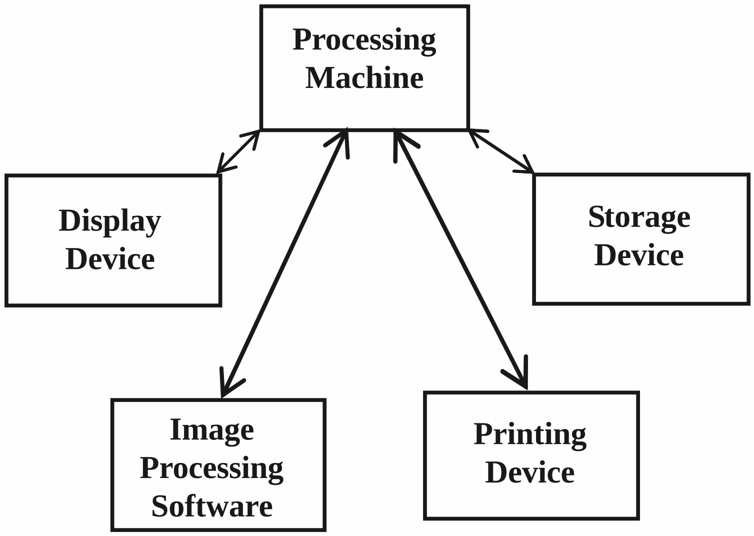

Fig. 10.3: Block diagram showing different components of a digital image processing system

Processing Machine (Computer)

It may be a general purpose computer according to task to be performed. The basic use of this device is that it will perform all digital image processing task off line.

Storage Device

Storage devices are used for storing of images for different purposes and use.

Display Device

It is used for displaying data. Example of a display device is generally a colour monitor.

Image Processing Software

Image processing software such as IGIS, ERDAS, ENVI and Geomatica are specially designed programming modules that perform specific tasks.

Printing Device

It is used for representing and storing image data in hard copy format. It could be laser, inkjet or any other printer.

It is important to note that following factors should be considered while selecting a digital image processing system:

- **Number of Analyst and Mode of Operation:** You should consider a software which could be accessed and interactively used for data processing by at least the number of people involved in the study.

- **Memory and Processing Specifications of Computer:** Processing of different types of digital remote sensing data require different processing capabilities and memory usage. You should choose a software that is compatible with the specifications of computer. You have or should buy a computer with minimum specification that is required to process the data of your interest.

- **Operating System:** The operating system must be powerful and easy to use. DOS, UNIX and WINDOW's are the most universally used operating systems. The chosen image processing software should be compatible with the operating system in your computer.

- **Storage:** Digital images are stored usually in matrix form with various multispectral bands and in different formats. Software which are capable of storing and processing the concerned image formats should be considered.

- **Display Resolution:** Different image types require different display resolution hence you should consider software which is capable of displaying highest resolution.

10.2.6 Steps in Digital Image Processing

It is now apparent to you that the subject of digital image processing is very broad. For our understanding, we can generalise the image processing into following four steps:

We shall discuss about all the four digital image processing steps in the next block, i.e. Block 4 of MGY-002.

- **Image Preprocessing**

  It is usually necessary to preprocess remote sensing data prior to its analysis because image data recorded by sensors contain errors which degrade quality of the image and cause the image to appear noise, blurred and distorted. The errors creep into during data acquisition process. Most common types of errors are geometric and radiometric errors. All these errors are corrected using suitable mathematical models at the time of preprocessing.

- **Image Enhancement**

  Image enhancement is carried out to improve the appearance of certain image features to assist in human interpretation and analysis. You should note that image enhancement is different from image preprocessing step. Image enhancement step highlights image features for interpreter whereas image preprocessing step reconstructs a relatively better image from an originally imperfect/degraded image.

- **Image Transformations**

  Image transformations are operations similar in concept to those for image enhancement. However, unlike image enhancement operations which are normally applied only to a single channel of data at a time, image transformations usually involve algebric operations of multi-layer images. Algebric operations such as subtraction, addition, multiplication, division, alogarithms, exponentials and trigonometric functions are applied to transform the original images into new images which display better or highlight certain features in the image.

- **Thematic Information Extraction**

  It includes all the processes used for extracting thematic information from images. Image classification is one such process which categorises pixels in an image into some thematic classes such as land cover classes based on spectral signatures. Image classification procedures are further categorised into supervised, unsupervised and hybrid depending upon the level of human intervention in the process of classification.

Check Your Progress I

Spend 5 mins

1) List out the advantages of digital image processing.

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   ....

   ....

   ....

2) Name the components in an image processing system.

   ....

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   ....

   ....

10.3 TYPES AND CHARACTERISTICS OF DIGITAL IMAGES

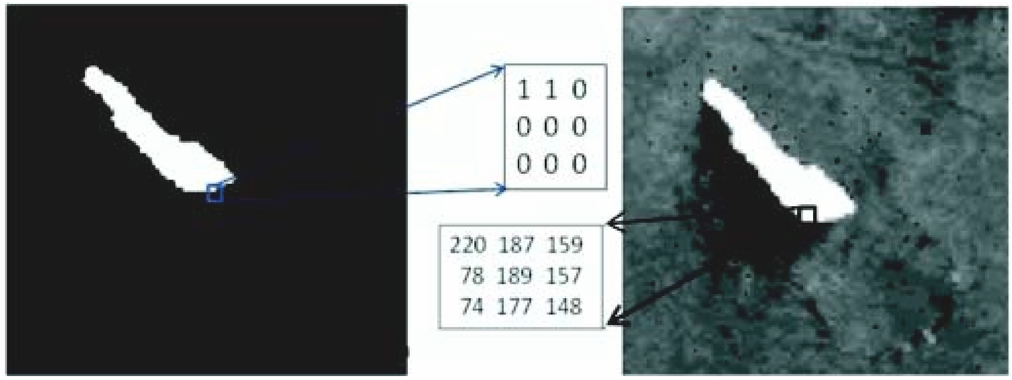
Before discussing about the image processing steps in the next block, it is essential to understand little more about the digital image. So, we shall now discuss about types of digital image and its characteristics.

10.3.1 Types of Digital Images

Digital images can be classified into several types based on their form or method of generation. The actual information stored in the digital image data is the brightness information in each spectral band and in general, digital images are of following three types:

a) Black and White or Binary image

Pixels in this type of images show only two colours, either black or white (Fig. 10.4a) and hence the pixels are represented by only two possible values for each pixel, 0 for black and 1 for white. Since a black and white image can be described in terms of binary values, such images are also known as *binary images* or *bi-level* or *two-level images*. This also means that the binary images require only a single bit (0 or 1) to represent each pixel hence storing of these kinds of images require only one bit per pixel. Inability to represent intermediate shades of gray limits usefulness of binary images in dealing with remote sensing or photographic images.



(a) (b)

Fig. 10.4: Representation of (a) black and white and (b) gray scale images. Note the range of values for the highlighted boxes in the two types of images

b) Gray Scale or Monochrome Image

Pixels in this type of images show white and black colours including the different shades between the two colours as shown in Fig. 10.4b. Generally, black colour is represented by 0 value, white by 255 and other in between gray shades by values between the two values. This range means that each pixel can be represented by eight bits or exactly one byte. In other words, storing of gray scale images require 8 bits per pixel.

c) Colour or RGB Image

Each pixel in this type of image has a particular colour which is described by the amount of red, green and blue colours in it (Fig. 10.5). Colour images are constructed by stacking three gray scale images where each image (i.e. band) corresponds to a different colour hence there are three values (one each for red, green and blue components) corresponding to each pixel.

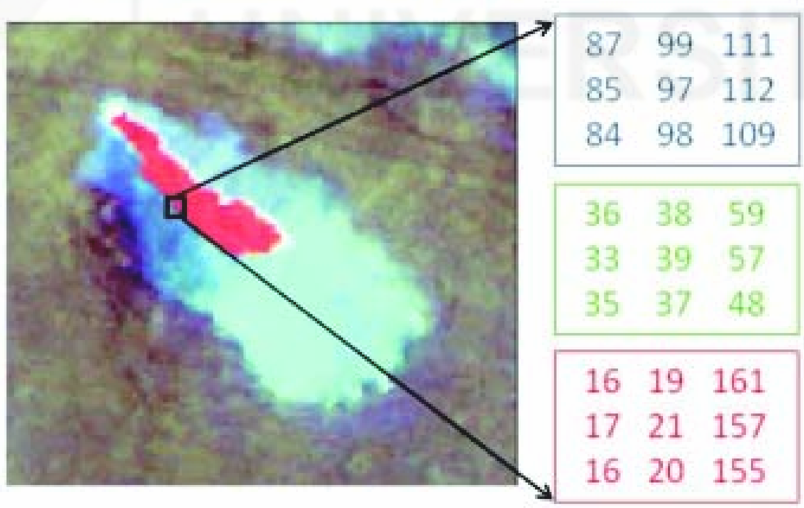


Fig. 10.5: Representation of a colour image. Note the range of values of its three components, i.e. red, green and blue

RGB (Red, Green and Blue) is the commonly used colour space to visualise colour images. Thus, RGB are primary colours for mixing light and are called *additive primary colours*. Any other colour can be created by mixing the correct amounts of red, green and blue light. If each of these three components has a range of 0 - 255, there could be a total of 2563 different possible colours in a colour image. Storing of a colour images require 24 bit for each pixel.

10.3.2 Characteristics of Digital Image

There are three basic measures for digital image characteristics:

- spatial resolution
- spectral resolution and
- radiometric resolution.

All these three types of image measures have already been described in Unit 5 *Image Resolution* of MGY-002, so it would not be repeated here. However, you should keep in mind that higher the resolution of an image, the more information the image contains.

10.3.3 Related Terminologies

You shall come across many terms while studying about digital image processing in the following units. Some of the commonly used terminologies related to digital images and their digital processing are introduced in this section so that you would become familiar with them.

Digital Number

In a digital image, each point/unit area in the image is represented by an integer digital number depending upon the brightness/intensity, which is often referred to as *digital number* or *DN* or *DN value*. The lowest intensity is assigned DN of zero and the highest intensity the highest DN number, the various intermediate intensities are assigned appropriate intermediate DNs. Thus, intensities over a scene are converted into an array of numbers, where each number represents the relative value of the field over a unit area. The range of DNs used in a digital image depends upon the number of bit data (Table 10.1), the most common being 8-bit type.

Table 10.1: Range of digital number with corresponding bit number

Bit number	Scale	DN range
7-bit or 2^7	128	0 - 127
8-bit or 2^8	256	0 - 255
9-bit or 2^9	512	0 - 511
10-bit or 2^{10}	1024	0 - 1023
11-bit or 2^{11}	2048	0 - 2047
12-bit or 2^{12}	4096	0 - 4095

Pixel Depth

It refers to the number of bits used to represent each pixel in *RGB space*. For example, if each pixel component of RGB image is represented by 8 bits, the pixel is said to have a depth of 24 bits.

Look Up Table

It gives an output value for each of a range of index values. A look up table is used to transform input data into a more desirable output format. For example, a gray scale picture of the planet Saturn will be transformed into a colour image to emphasise the differences in its rings. Contrast and colour values can be altered without modifying original digitised image, and an adjustable curve may be utilised to interactively alter values present in the look up table.

Band

In a multispectral sensor such as those aboard the Landsat satellites, information from different wavelengths of light is collected as in a digital camera but there are two major differences. First is that instead of limiting itself to the visible wavelengths (red, green and blue) a much broader range of wavelengths are detected. Second difference is that instead of automatically combining information from the different wavelengths to form a picture, the information for each specific wavelength range is stored as a separate image. This image is commonly called a *band.* In other words, images obtained in different wavelengths together form a multispectral image and each image is known as a *band* or *layer* or *channel*.

10.4 CONCEPT OF TRUE AND FALSE COLOUR COMPOSITE

You can learn about the concept of true and false colour composites only when you have read about digital image. If you recognise structure and principle of a colour TV tube, you would know that tube is composed of three colour guns of red, green and blue. The red, green and blue colours are known as *primary colours* and any other colour can be matched by proper proportions of these three colours. The mixture of the light from these three primary colours can produce any colour on a TV. As to the human eyes, the image that appears just like the original subject would be as a blue sky appears blue, a red apple appears red and a green tree appears green. Let us now try to comprehend how human eyes determine a colour. Fig. 10.6 shows horizontal cross section of human eye. A human eye consists of three membranes enclosing the eyes which are given below:

a) cornea and sclera that are the outer covers of eyes

b) choroid that has further two parts called ciliary body and iris diaphragm and

c) retina that has two classes of receptors called cones and rods.

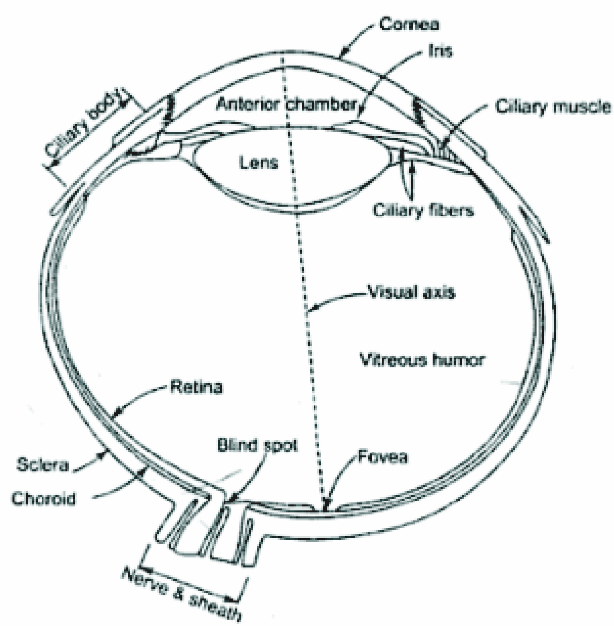


Fig. 10.6: Cross section view of human eye

Besides these three types of membranes, eyes also have one lens. When eyes are properly focused, light from an object outside the eyes is imaged on retina. Human retina has three types of cones. The response by each type of cone is a function of the wavelength of the incident light; it peaks at 440 nm (blue, B), 545 nm (green, G) and 680 nm (red, R), i.e. each type of cone is primarily sensitive to one of the primary colours: blue, green or red. A colour perceived by a person depends on the proportion of each of these three types of cones being stimulated and, thus, can be expressed as a triplet of numbers (R, G, B). These three values define a 3-dimensional colour space called *RGB colour space.*

A colour space is a mathematical system for representing colours.

Digital image colour display is based entirely on this colour theory. This can be explained with example of a colour TV that is composed of three precisely registered colour guns- red, green and blue. In the blue gun, pixels of an image are displayed in blue of different intensity (e.g., dark blue, light blue) depending on their DNs. The same is true of the green and red guns. Thus, a colour image is generated when red, green and blue bands of a multi-spectral image are displayed in red, green and blue guns of a TV or computer monitor simultaneously. Illustration in Fig. 10.7a shows the typical demonstration of additive light mixtures, made by shining three overlapping squares of filtered light onto an achromatic (gray or white) surface. If the surface is illuminated by both red and green lights but not by the blue light, then eye responds with the colour sensation of yellow. Magenta colour results from the mixture of red and blue light, and cyan from the mixture of blue and green (Table 10.2). In additive colour mixing, yellow and blue do not make green but white.

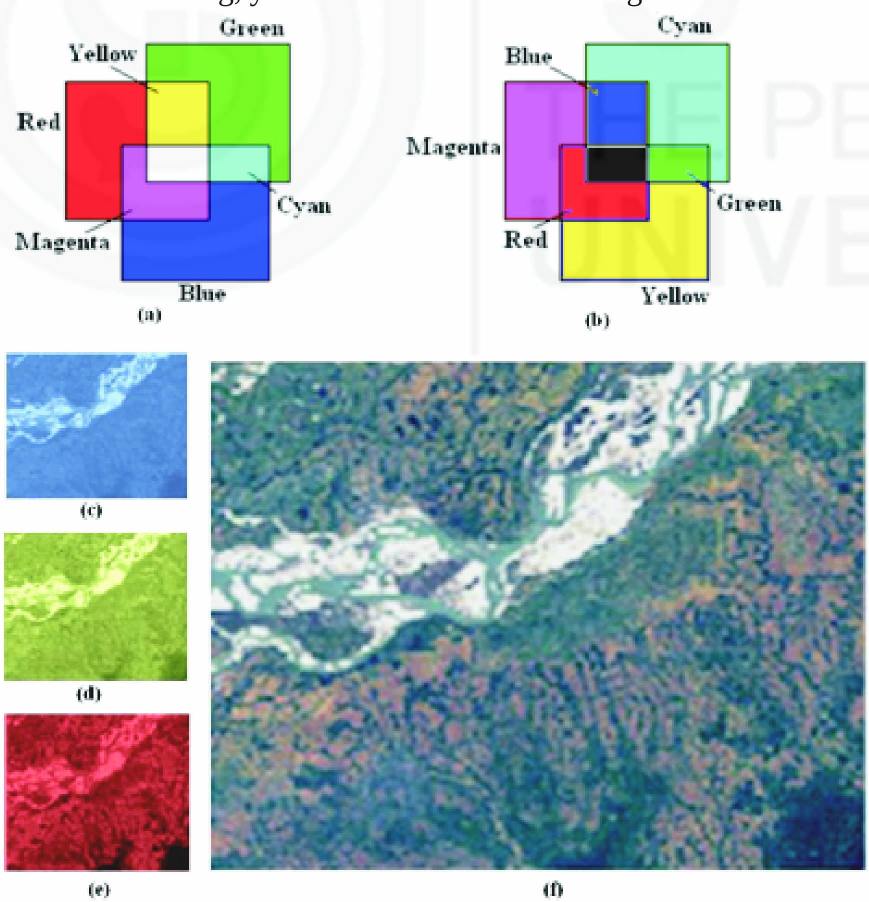


Fig. 10.7: Illustration of (a) additive and (b) subtractive colour mixtures. Images from (c) to (f) show additive colour image display. (c), (d) and (e) are the three images displayed in blue, green and red guns, respectively of a computer monitor and (f) is the resultant colour image

Table 10.2: Mixing of primary colours and the resultant colour produced

Combination of primary colours			Resultant colour
-	Green	Blue	Cyan
Red	-	Blue	Magenta
Red	Green	-	Yellow
Red	Green	Blue	White
-	-	-	Black

We see light colours by the process of emission from the source but we see pigment colours by the process of reflection (i.e. light reflected off an object). Colours which are not reflected are absorbed (subtracted). When source of colour is pigment, the result of combining colours is different from when source of colour is light. Cyan, magenta and yellow (CMY) are called the *subtractive primary colours* (Fig. 10.7b). Subtractive colour mixing occurs when light is reflected off a surface or is filtered through a translucent object. Perhaps, easiest way to think about it is to realise that red pigment absorbs green and blue, blue pigment absorbs red and green, and green pigment absorbs red and blue and the result is completely black (Fig. 10.7b).

Thus, RGB colour cube is defined by the maximum possible DN level in each component of display. Any image pixel in this system may be represented by a vector from the origin to somewhere within the colour cube. Most standard RGB display system can display 8 bits per pixel per channel, up to 24 bits = 256^3 different colours. This capacity to display is enough to generate a *true colour* image (Fig. 10.7f).

As we know colours lie in the visible spectral range of 380 - 750 nm, they are used as a tool for information visualisation in colour display of all digital images. Thus, for the display of a digital image, the assignment of each primary colour for a spectral band can arbitrarily depend on the requirements of application, which may not necessarily correspond to the actual colour of spectral range of the band hence let us discuss two terms which are commonly used in the context of remote sensing images viz. true colour composite and false colour composite.

True Colour Composite

If we display three image bands of a remote sensing data acquired in red, green and blue spectral ranges in red, green and blue colour guns/plane of a monitor, respectively, then a *true colour composite* (TCC) image is generated (Fig. 10.8). In other words, if we display the blue band in blue plane, green band in green plane and red band in red plane of colour monitor for display then a true colour composite is produced.

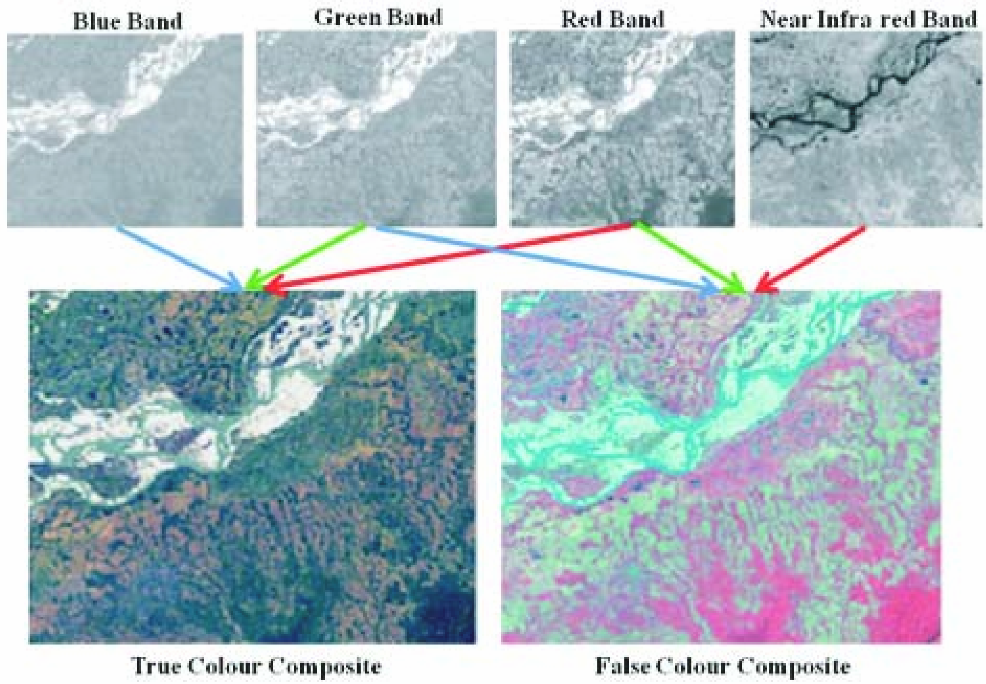


Fig. 10.8: True and false colour composites generated from blue, green, red and near-infrared (NIR) bands of Landsat images

False Colour Composite

Sensors such as LISS III are designed to acquire images in green, red, NIR and middle infrared wavelengths of the electromagnetic spectrum and not in blue wavelength. In such cases, where there is no band in visible region or there are images acquired beyond the visible region, images can still be displayed in monitor however by assigning and displaying images in colour planes of the monitor to which they do not belong. Such kinds of colour image display are known as *false colour composites* since they do not represent the true colour as we would see on ground. In other words, false colour composites are artificially generated colour images in which different bands of a multispectral data are displayed in image planes other than their own (Fig. 10.8). For example, in the false colour composite shown in Fig. 10.8, green band is assigned to blue plane, red band is assigned to green plane and NIR band is assigned to red plane of the computer monitor for display. False colour composite is the general case of an RGB colour display in any combination, however, the true colour composite is only a special case of it.

In many of the sensors such as LISS III, they were not designed to acquire images in blue wavelength because of the noise problem and images were acquired in many other wavelength regions including infrared. In such cases, false colour composites were generated without the presence of a blue band. *Standard false colour composite* (SFCC) is a typical example of false colour composites in which colour composite is generated by shifting bands in such a way that NIR band is displayed in red plane, red band in green and green band in blue plane of the monitor. In the SFCC, healthy vegetation appears in shades of red because vegetation absorbs most of green and red energy but reflects approximately half of incident infrared energy. SFCC effectively highlights any vegetation distinctively in red (Fig. 10.8). Images displayed in any other band combination are called broadly called false colour composites.

Spend 5 mins

Check Your Progress II

1) Digital images are sampled and mapped as a grid of dots called ....
....

2) In a digital image, each point in the image is represented by an integer referred to as ....

10.5 IMAGE HISTOGRAM AND ITS SIGNIFICANCE

Let us now study about image histogram and its significance. Most commonly, remote sensing images are of 8 bits hence, the range of DNs varies between 0 and 255. If you tabulate frequencies of occurrence of each DN in an image, it can be graphically presented in a histogram wherein range of DNs is presented on abscissa and frequency of occurrence of each DN on the ordinate as shown in Fig. 10.9. In the context of remote sensing, histogram can be defined as a plot of the number of pixels at each pixel value within each spectral band.

Histograms in general are frequency distribution describing frequency of DNs occurring in an image. Histogram basically is a graph that represents maximum range of DNs that a remote sensor captures in 256 steps (0 = pure black and 255 = pure white) for an 8 bit data. Histogram provides a convenient summary of brightness (pixel values) in an image. It is used to depict image statistics in an easily interpreted visual format.

2	3	4	7	6
1	2	4	5	6
1	1	5	6	6
5	1	5	3	4
0	1	2	3	4

Image

Pixel value	Count
1	2
2	3
3	4
4	7
5	4
6	3
7	2
Total	30

Histogram

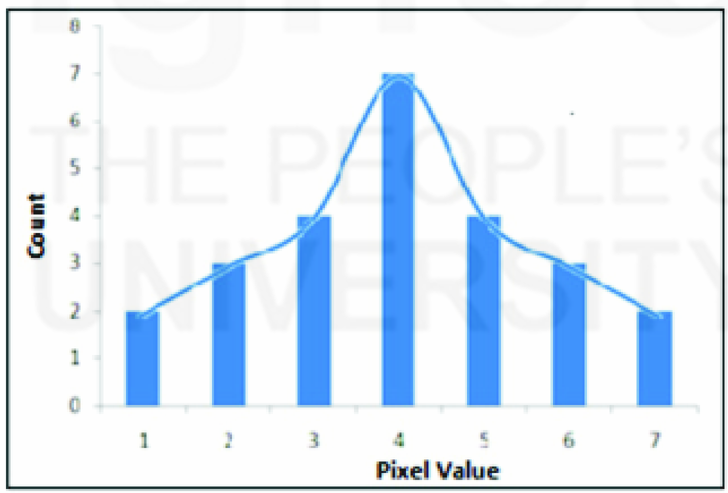
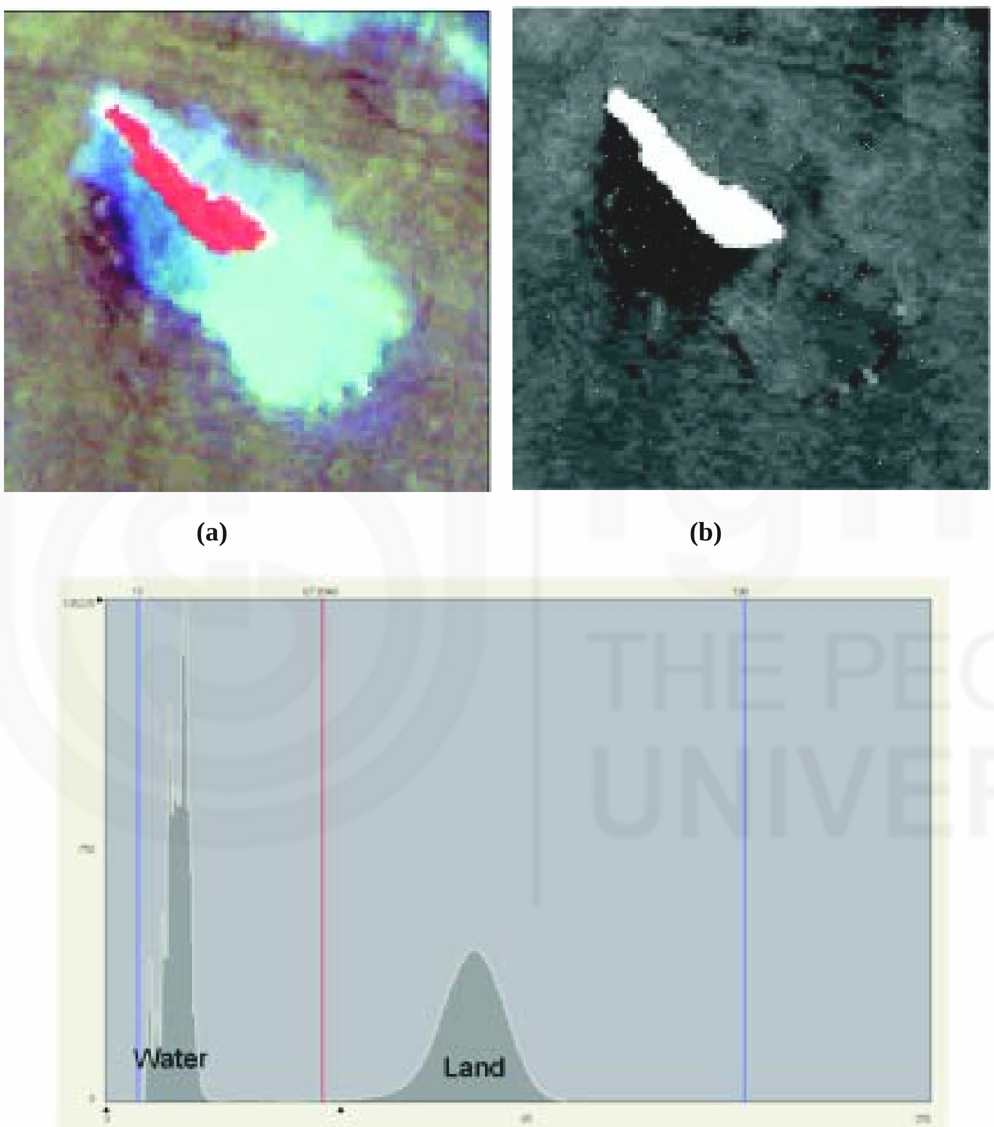


Fig. 10.9: Table in left is showing DNs of a hypothetical image. Central table shows frequency of occurrence of each DN. Figure at the right is the graphical representation i.e. histogram of the central table

Histogram, shown in Fig 10.9, looks like a mountain peak and its highest bar is a representative of maximum concentration of a particular pixel value. Left to right direction of the histogram is related to the darkness (minimum value lies at left side) and lightness (maximum value lies at right side) of image, respectively, while up and down directions of histogram (valleys and peaks) correspond to brightness (or colour in multispectral image) information. If an image is too dark, histogram will show higher concentration in the left side and if the image is too bright its histogram will show higher concentration in the right side. This will become easier to understand if you look at histograms produced by a day and a night time image. Each image has its own unique histogram, and with a histogram, it is easy to determine certain types of problems in an image. For example, it is easy to conclude if an image contains too bright or dark pixels by visual inspection of its histogram.

Careful inspection of histogram can also give us an idea about the dominant types of features in the image. For example, Fig. 10.10c shows histogram of an image representing coastal area, which shows two peaks in histogram. The large peak at the left represents water pixels and other peak represents land pixels. Images of coastal areas show two distinct peaks in NIR band histogram, one peak having lower DN values corresponds to water pixels and other peak having higher DN values represents land pixels.



(a) (b)

(c)

Fig. 10.10: (a) Jolly Boys island in the Andaman group of islands as seen in a false colour composite, (b) gray scale image of NIR band clearly showing land (bright) and water (dark) pixels and (c) histogram of NIR band. Note two distinct peaks in histogram for water and land pixels

Now, you have implicit that for a low contrast image, histogram will not be spread equally, i.e. histogram will be narrow and tall covering a short range of pixel values. For a high contrast image, histogram will have an equal spread of pixel values and produce short and flat (wide) histograms covering a wide range of pixel values.

Histograms always depend on the visual characteristics of the scene captured in the image, so there is no single ideal histogram that exists. While a given histogram may be optimal for a specific scene, it may be entirely unacceptable for another. For example, the ideal histogram for an astronomical image would likely be very different from that of a good landscape image. So, now you have understood that significance of a histogram lies in the fact that it provides an insight about image contrast and brightness and also about the quality of the image.

10.6 ACTIVITY

To acquire more knowledge about image histogram you can practice the activity given below:

Capture a picture by your digital camera in day light and capture the same scene in night. Process these two images in digital image processing software and create histograms for them. Compare histograms of these two images and observe differences in them. You may also capture images of different objects at a particular time and see differences in histogram.

10.7 SUMMARY

In the present unit, you have studied the following

- Images are a way of recording and representing information in a visual form. A digital image is composed of finite number of elements called pixels.
- A digital image corresponds to a two-dimensional array of pixels and each pixel has a particular location and value.
- Digital images are of three types: binary or black and white, gray scale and colour or RGB image.
- Digital image processing is a collection of techniques for the manipulation of digital images by computers.
- Components of a digital image processing system include processing machine, software and storage and printing devices. Basic steps in digital image processing include image preprocessing, image enhancement, image transformation and image classification.
- Primary colours are those that cannot be created by mixing other colours. Because of the way we perceive colours using different sets of wavelengths, there are three primary colours; red, green and blue. Any colour can be represented as some mixture of these three primary colours.
- Histograms are frequency distribution of pixel values in an image. The brightness of an image can be improved by modifying histogram of the image.

10.8 UNIT END QUESTIONS

1) Define an image and a digital image.
2) Discuss major steps in digital image processing.
3) Write about the types of digital image.
4) Define true and false colour composites.
5) What do you mean by image histogram?

10.9 FURTHER/SUGGESTED READING

- Jensen, J.R. (1986), *Introductory Digital Image Processing - A Remote Sensing Perspective*. Prentice Hall, New Jersey.
- Reddy, M. A.(2006), *Textbook of Remote Sensing and Geographical Information Systems*, BS Publications, Hyderabad.

10.10 ANSWERS

Check Your Progress I

1) Advantages of digital image processing are:
   - images can be identically duplicated during reproduction and distribution without any change or loss of information
   - visualisation of greater details
   - images can be processed to generate new images without altering the original image
   - faster extraction of quantitative information and
   - repeatability of results.
2) Components of an image processing system are processing machine (computer), image processing software, storage device and display device.

Check Your Progress II

1) Pixels.
2) Digital number (DN).

Unit End Questions

- Refer to subsections 10.2.1 and 10.2.2
- Refer to subsection 10.2.6
- Refer to subsection 10.3.1
- Refer to section 10.4
- Refer to section 10.5

GLOSSARY

Ancillary data: It include any type of data/information (spatial and non-spatial) that may be of value in the image classification process (i.e. pre, post and during classification). It comprises any type of information likes slope, height, aspect, geology, soils, hydrology, transportation networks, political boundaries, vegetation maps and so on.

Bhuvan: It is the Indian Google Earth launched by ISRO in its own version. Bhuvan is based on the images taken by IRS satellites and it can be downloadable from Indian Earth observation visualisation.

Bit: It is the lowest level of electronic value in a digital image. It defines a pixel's colour value in combination with other bits. Each bit can have one of two values either 1 or 0.

Brightness: It is the amount of light received by the eye regardless of colour. The brightness of a colour identifies how light or dark the colour is. Any colour whose brightness is zero is black, regardless of its hue or saturation.

Colour composite: It is a colour image prepared by combining individual band images in which each band (up to a maximum of 3) is assigned one of the three additive primary colours such as blue, green and red.

Contrast stretching: Improving the contrast of images by digital processing. The original range of digital values is expanded to utilise the full contrast range of the recording film or display device.

Colour space: The parts of the spectrum used to describe an image. Colour spaces vary in their scope according to the range of colours involved.

False colour composites: These are artificially generated colour images in which blue, green and red colours are assigned to the wavelength regions to which they do not belong.

GPS (Global Positioning System): It is a satellite based location system that gives accurate position (latitude, longitude and height) and navigational information. At present there are 24 GPS satellites.

Gray scale: A calibrated sequence of gray tones ranging from black to white.

Ground truthing: The process of collection of ground truth data that helps to link the image data to the ground reality in order to verify the image features.

Image reading: It is an elemental form of image interpretation and corresponds to simple identification of objects using such image interpretation elements as shape, size, etc.

Image measurement : Represents the extraction of physical quantities such as length, location, height, density, temperature and so on by using reference data or calibration data deductively or inductively.

Image analysis : Understanding of the relationship between interpreted information and the actual status or phenomenon, and to evaluate the situation.

Interpretation key: Criteria for identification of an object with elements of interpretation.

Land cover: Physical material present on the surface e.g., forest.

Landforms: Natural features of a land surface e.g., mountains, plateaus, plains, etc.

Landsat: Comprises a series of unmanned Earth-observing satellites jointly managed by NASA and U.S. Geological Survey (formerly called Earth Resources Technology Satellite – ERTS).

Land use: Description of the way that humans are utilising any particular piece of land for one or many purposes, e.g., for agriculture, industry, or residence.

Light: EMR within 400-700 nm in wavelength that is detectable by the human eye.

Location: A specific position in the physical space.

NIR (Near-infrared): A subdivision in the infrared band somewhere between the 800 nm and 2,500 nm wavelengths.

Noise: Random or repetitive events that obscure or interfere with the desired information.

Picture element: It is the smallest element in a digital image. In a digitised image this is the area on the ground represented by each digital value. Because the analogue signal from the detector of a scanner may be sampled at any desired interval, the picture element may be smaller than the ground resolution cell of the detector. It is commonly abbreviated as pixel.

Scale: Ratio of the distance on an image to the equivalent distance on the ground.

Thematic map: The extracted information that will be finally represented in a map form.

True colour composite: It looks like a natural colour composite image in which spectral bands are combined in such a way that the appearance of the displayed image resembles a visible colour photograph.

Stereoscopy: Science of viewing a pair of stereoscopic photographs or images by looking at the left image with the left eye and the right image with the right eye.

Aerial camera: A precision camera specifically designed for use in aircrafts.

Aerial photograph: Photograph taken from an airborne platform using a precision camera.

Densitometry: Science of making accurate measurement of film density.

Densitometer: An instrument that measure image density by directing a light of known brightness through a small portion of the image, then measuring its brightness as altered by the film.

Height finder: An instrument designed for use with a stereoscope. It permits estimation of topographic elevation or of the heights of features from stereoaerial photographs.

ABBREVIATIONS

AVHRR	:	Advanced Very High Resolution Radiometer
AWiFS	:	Advanced Wide Field Sensor
CMY	:	Cyan, Magenta and Yellow
DEMs	:	Digital Elevation Models
DN	:	Digital Number
GPS	:	Global Positioning System
HRV	:	High Resolution Visible
IRS	:	Indian Remote Sensing Satellites
ISRO	:	Indian Space Research Organisation
LISS	:	Linear Imaging Self-Scanning
LRF	:	Lake Reserved Forest
LULC	:	Land Use/Land Cover
MMU	:	Minimum Mapping Unit
MRI	:	Magnetic Resonance Imaging
NH	:	National Highway
NIR	:	Near-infrared
NOAA	:	National Oceanic and Atmospheric Administration
NRSC	:	National Remote Sensing Centre
PAN	:	Panchromatic
RGB	:	Red, Green and Blue
SFCC	:	Standard False Colour Composite
SPOT	:	Satellite Pour I'Observation de la Terre
SWIR	:	Shortwave Infrared
TCC	:	True Colour Composite
TM	:	Thematic Mapper
WiFS	:	Wide Field Sensor