KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University)

(Established Under Section 3 of UGC Act 1956)

Coimbatore- 641 021

(For the candidates admitted from 2016 onwards)

DEPARTMENT OF CIVIL ENGINEERING

SUBJECT CODE: 16BECE7E07 **SUBJECT: REMOTE SENSING TECHNIQUES AND APPLICATIONS**

SEMESTER:V **CLASS: III Civil Engineering** **L T P C = 3 0 0 3**

Course Outcomes:

- To gain a sound fundamental understanding of the GIS and remote sensing technologies
- To understand the basic principles underlying the GIS/model-based management of water resources and environment.
- To become familiar with the GIS-based analytical and problem-solving techniques for sustainable planning and management of water resources and environmental problems.
- Different types of remotely sensed images and data available for water resource applications.

UNIT I

Introduction: Definition – Physics of remote sensing – electromagnetic radiation (EMR) – remote sensing windows – interaction of EMR with atmosphere, earth surface, soil, water and vegetation – platform and sensor – image interpretation.

UNIT II

Land Use Studies: Definition of land use – land use / land cover classification – schemes and levels of classification systems with RS data – land use mapping – change detection – urban land use planning, site suitability analysis, transportation planning.

UNIT III

Water Resources : Area assessment of surface water bodies – Capacity survey of water bodies – mapping of snow- covered areas – flood risk zone mapping – identification of groundwater potential zones, recharge areas – droughts-definition-drought assessment and management**.**

UNIT IV

Agriculture, Soil And Forestry: Crop inventory mapping – production estimation – command area monitoring – soil mapping – crop stress detection - estimation of soil erosion – forest types and density mapping – forest fire risk zone mapping.

UNIT V

Earth Science: Lithology – lithological mapping – structural mapping – Geomorphology – nature and type of landforms – identification – use of remote sensing data for land slides – targeting mineral resources – Engineering geology and Environmental geology.

TOTAL HRS: 45

TEXT BOOKS:

Sl.No	**Title of Book**	**Author of Book**	**Publisher**	**Year of Publishing**
1	Remote sensing methods and application	Michael Hord, R	John Wiley and Sons, New York	2004
2	Remote sensing principles and interpretation	Sabins, F.F.Jr	W.H.Freeman &Co.New York	2007

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1	Remote and Image Sensing interpretation	Lillesand, T. M and Kicter R.W	John Willey and sons, inc. New York	2002
2	Application of Remote sensing in Agriculture	Steven, M.D , and Cllark, J.A	Butterworths, London	1990
3	Manual for Forest mapping and Damage detection using satellite data- Space Applications Centre,1990, Report No.IRS-UP/SAC/FMDD/TN/16/90,1990			
4	Manual of Remote Sensing Vol. II. American Society of Photogrammetry			

WEBSITES:

- http://www.icivilengineer.com
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DEPARTMENT OF CIVIL ENGINEERING

LECTURE PLAN

REMOTE SENSING TECHNIQUES AND APPLICATIONS (16BECE7E07)

LECTURER : Dr. M. Natarajan
SEMESTER : V (2018-2019)ODD
NUMBER OF CREDITS : 3
COURSE TYPE : Regular Course

S.No	Hours	Topics to be Covered	Text Book	Page No.
UNIT I- Introduction				
1.	1	Definition – Physics of remote sensing	T2	1,3,4
2.	1	Electromagnetic radiation (EMRremote sensing windows)	T2	27
3.	1	Interaction of EMR with atmosphere, earth surface, soil, water and vegetation	T2	22
4.	1	Interaction of EMR with atmosphere, earth surface, soil, water and vegetation	T2	37
5.	1	Interaction of EMR with atmosphere, earth surface, soil, water and vegetation	T2	37
6.	1	Platform and sensor	T2	40
7.	1	Platform and sensor	T2	48
8.	1	Image interpretation	T2	95
9.	1	Image interpretation	T2	115
				Total 09 hours
UNIT II- Land Use Studies				
10.	1	Definition of land use	T2	109-133
11.	1	Land use / land cover classification	T2	109-133
12.	1	Schemes and levels of classification systems with RS data	T2	109-133
13.	1	Land use mapping	T2	109-133
14.	1	Land use mapping	T2	109-133
15.	1	Change detection	T2	109-133
16.	1	Urban land use planning	T2	109-133
17.	1	Site suitability analysis	T2	109-133
18.	1	Transportation planning	T2	109-133
				Total 09 hours
UNIT III- Water Resources				
19.	1	Area assessment of surface water bodies	T2	195-267
20.	1	Capacity survey of water bodies	T2	195-267
21.	1	Mapping of snow	T2	195-267
22.	1	Covered areas	T2	195-267
23.	1	Flood risk zone mapping	T2	195-267
24.	1	Identification of groundwater potential zones	T2	195-267
25.	1	Identification of groundwater potential zones	T2	195-267

26.	1	Recharge areas – droughts	T2	195-267
27.	1	Definition-drought assessment and management	T2	195-267
				Total 09 hours
		UNIT IV- Agriculture, Soil And Forestry		
28.	1	Crop inventory mapping	T2	137-156
29.	1	Production estimation	T2	137-156
30.	1	Command area monitoring	T2	137-156
31.	1	Soil mapping	T2	137-156
32.	1	Soil mapping	T2	137-156
33.	1	Crop stress detection	T2	137-156
34.	1	Estimation of soil erosion	T2	137-156
35.	1	Forest types and density mapping	T2	137-156
36.	1	Forest fire risk zone mapping	T2	137-156
				Total 09 hours
		UNIT V- Earth Science		
37.	1	Lithology	T2	398-404
38.	1	Lithological mapping	T2	398-404
39.	1	Structural mapping	T2	398-404
40.	1	Geomorphology	T2	398-404
41.	1	Nature and type of landforms	T2	398-404
42.	1	Identification	T2	398-404
43.	1	Use of remote sensing data for land slides	T2	398-404
44.	1	Targeting mineral resources	T2	398-404
45.	1	Engineering geology and Environmental geology	T2	398-404
				Total 09 hours
				Total 45 hours

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4	Manual of Remote Sensing Vol. II. American Society of Photogrammetry			

LECTURE NOTES

2016

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CONTENTS

1. SENSORS AND PLATFORMS FOR ACQUISITION OF AERIAL AND SATELLITE IMAGE DATA

This chapter will discuss the various sensors that are available for the acquisition of image and other data for applications in photogrammetry and remote sensing, as well as for data collection for GIS, and subsequent analysis. 'Photogrammetry and remote sensing' are often traditional terms used for the extraction of metric and semantic information respectively from aerial, including unmanned aerial systems (UAS, also referred to as UAV, Remote Piloted Aerial Systems RPAS and drones) and satellite images, as well as from images taken at close range to an object. The terms will be used often in these notes. A typical definition is:

Photogrammetry and Remote Sensing is the art, science, and technology of obtaining reliable information from non-contact imaging and other sensor systems about the Earth and its environment, and other physical objects and processes through recording, measuring, analyzing and representation.

1.1 Types of image sensors

Sensors used in photogrammetry and remote sensing can be separated into 'passive' and 'active'. Passive sensors simply record light, usually solar radiation that is projected by a lens system onto a digital sensor. In the case of close range applications (distances nominally less than 300 metres), the lighting may be from artificial sources. Active sensors emit their own illumination and then record the time and intensity of the signal that is reflected from the ground or other objects.

Passive Sensors

- Digital cameras and film cameras, which are referred to 'analogue photographic sensors', record visible and near infra-red electro-magnetic radiation. Film images can be digitised for use in digital photogrammetric systems although this process is being phased out.
- Pushbroom or Whiskbroom (sometimes referred to as electro-optical sensors), which scan the terrain surface, comprising special devices for detecting and then recording multispectral images of reflected electromagnetic radiation.

Active Sensors

- Radar sensors emit microwave radiation, and record the time of transmission to the ground and back to the sensor, as well as the intensity of the reflected radiation from the terrain surface. All current systems are based on Synthetic Aperture Radar (SAR). Interferometric SAR (InSAR) is a technique used to determine elevations from SAR images based on the phase differences between SAR images received by two separate antennas.
- Airborne Laser Scan (ALS) or lidar (**Li**ght **D**etection **a**nd **R**anging and also written as LiDAR) are techniques for determining elevations on the terrain surface or characteristics of vegetation canopy from aircraft or satellite. Terrestrial Laser Scanners (TLS) are ground based lidar systems. Only airborne lidar sensors will be discussed in this course.
- Other forms of active imaging may also be used for measurement, such as electron microscope and X-rays.

1.2 Platforms

The platforms on which the sensors are placed may be an aeroplane, UAS (unmanned aerial system), a satellite in space, or a suitable mount on or near the terrain surface, if close range imaging is undertaken. The principles of the geometry of sensors will not normally be affected by the platform on which they are placed. However, accuracies of extracted information from images will depend on the distance of the sensor to the object. For aerial photography, the positions of the sensor will be determined by Real-Time Kinematic (RTK) from GNSS receivers installed on the aircraft, while tilts of the camera may be determined by an inertial measuring unit (IMU), also referred to as inertial navigation system (INS). The three position and three tilt parameters are referred to as the parameters of *exterior orientation* of the sensor. These systems may be integrated to provide what is referred to as *direct orientation* of the sensor. The exterior orientation of an earth observation satellite in space may be determined by GNSS, satellite tracking systems and star trackers. In close range photogrammetry, the position of a camera can usually be determined on the ground by standard survey methods.

1.3 Digital Aerial Cameras

Digital aerial cameras have only become available in about the last 15 years and have now replaced film cameras in many parts of the world. Their design must satisfy the need to produce high quality images and also provide a wide coverage of the terrain surface. Modern digital aerial cameras continue to be improved as new digital imaging technologies are developed. The characteristics of modern digital aerial cameras are as follows:

- They acquire high spatial resolution images of more than 200 Mpixels, comprising Ground Sampling Distance (GSD) of 5 cm and larger with high geometric accuracy
- They have adequate angles of field of coverage for efficient for geospatial information extraction
- They take advantage of the particular characteristics of digital image acquisition, with quantization levels of 11 bit or 12 bits, that is, 2048 or 4096 grey scale values and improved image quality.
- They acquire 4 bands of multispectral images with the same or lower spatial resolution as the panchromatic images.

Currently digital aerial cameras used in photogrammetry are classified as '*high-resolution'* and '*medium resolution'*. High spatial resolution digital aerial cameras have the potential to collect hundreds of Mpixels while medium spatial resolution cameras usually are based on a smaller single area array chips with about100 Mpixel.

Advantages of using digital images are:

- Image processing for target location, automatic height measurement and semi-automatic information extraction can be carried out on the image data, using stereo observation on the screen
- Digital orthophotos can be automatically derived from the data, thus providing for much greater flexibility in correcting variations in density of neighbouring images
- Future developments based on machine vision techniques will enable the automatic extraction of semantic information from the images

Disadvantages of using digital images:

- An analogue photo is an extremely efficient way to store information about an object and can be stored for decades.
- Algorithms for the automatic extraction and identification of information from images have not been developed, which impacts on the type of products that can currently be extracted from digital aerial images.
- Storage of digital image data requires regular backups onto new storage technology and as the old storage devices become obsolete.

Since digital aerial cameras are undergoing continual development and new models and types are being released onto the market on a regular basis. In the development of the new digital high spatial resolution aerial cameras two approaches have been adopted as described below.

1.3.1 High Spatial Resolution Digital Aerial Cameras

(i) Systems based on CCD linear arrays - referred to as 'Pushbroom' sensors. Linear array scanners acquire data by scanning the terrain with one or more linear arrays oriented normal to the flight direction as the aircraft moves over the terrain, (likened to a broom sweeping a surface). The Leica system comprises three linear arrays, one pointing forward, one pointing vertically and one pointing backwards to acquire **three separate overlapping images** of the terrain surface. The acquisition of overlapping images is essential for determining 3D coordinates of objects, including elevations, as will be described later in these notes. The systems are usually designed for acquiring panchromatic (ie black and white) and also colour or multispectral images including in the short wavelength infrared region of the spectrum (CIR – colour and infrared), with wavelengths up to about 0.9 μm wavelength, at the same or reduced resolution as the panchromatic images. **An integrated GNSS/IMU (Inertial Measuring Unit) system is essential** for this camera configuration for determining camera position and tilts, because the image acquisition is a continuous process and not frame based. Images from pushbroom sensors cannot be processed by standard frame image software. An example of this type of digital camera is:

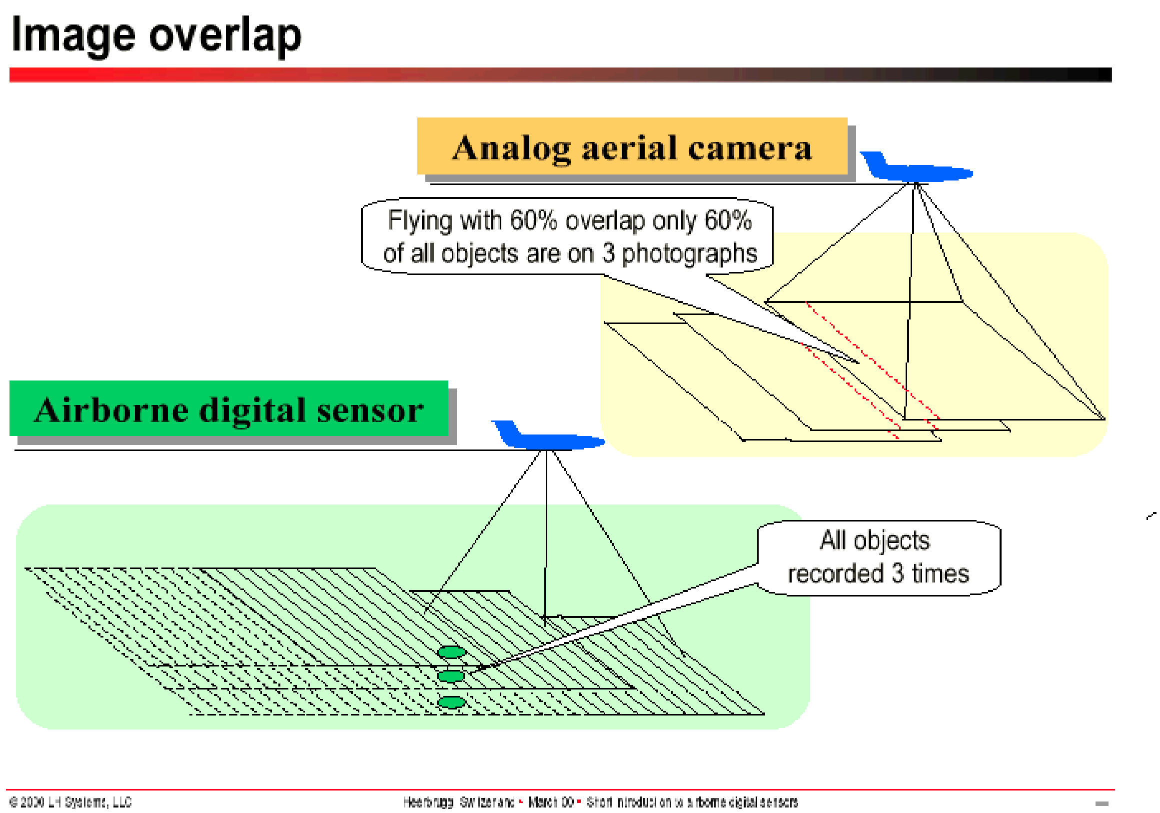


Figure 1.1 Comparison of linear array camera of Leica Geosystems (ADS100) and normal frame camera configurations

- **Leica ADS100** (Figure 1.1) acquires overlapping panchromatic and multi-spectral images, all with the same resolution, by 3 CCD linear arrays, looking forward, vertical and aft, by the SH100/SH120 camera heads.

(ii) Frame systems based on area arrays. These systems involve single large rectangular array or multiple small area arrays whose images are stitched together to form larger usually rectangular frame images. These images can be processed using standard digital photogrammetric software for frame images. GNSS/IMU systems are not essential for the operation of this type of camera, but some or all components of such a system may be included as an option. Cameras based on this configuration are:

- The DMC (Leica) cameras. The 1st generation was composed of 4 separately directed camera heads (7kx4k) for panchromatic images which were stitched together, and 4 camera heads (3kx2k) for 4 channels of multispectral images, each pointed so that they cover the required area of the terrain. The 2nd DMCII and 3rd generations DMCIII (various versions with different chip sizes are available) are based on a single monolithic area array. The multispectral images have a resolution 3.2 times less than the panchromatic images. The 3rd generation with 390 Mpixels is based on CMOS sensor (as opposed to CCD sensor for DMCII) with pixel sizes of 3.9 μm, 26113 pixels across the swath and 15,000 in the flight direction, together with mechanical forward motion compensation (FMC).
- The Vexcel UltraCam (Figure 1.2) is based on 'syntopic' imaging by 9 small format frame cameras for the panchromatic images, which are recorded sequentially during flight with 4 CCD arrays, so that the image acquisition for all arrays is based on the perspective centres of the cameras cones being in the same position. The separate images are stitched together to form a single area array. The multispectral images are acquired with 4 cameras cones each on a single CCD array at a lower resolution than the panchromatic images.

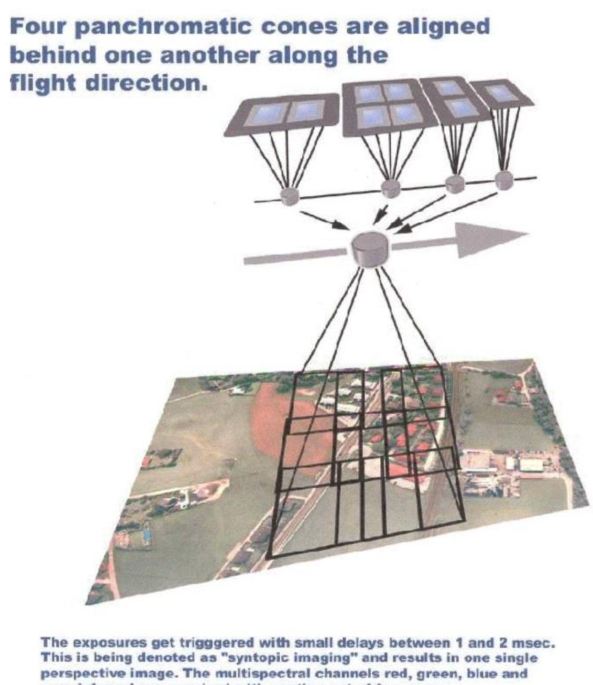


Figure 1.2 Digital frame camera (UltraCam) configuration by the Microsoft Vexcel Camera

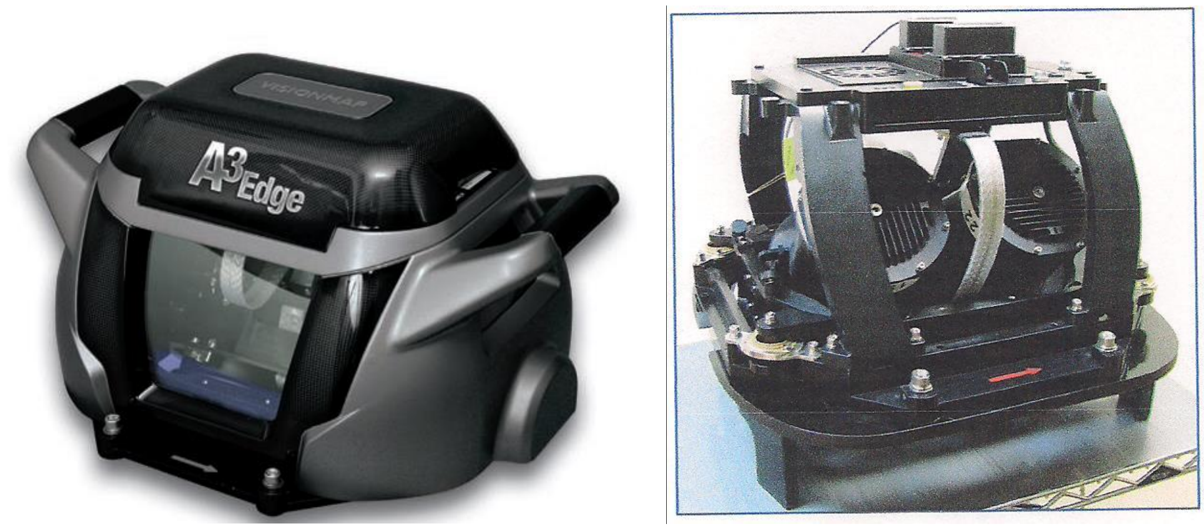


Figure 1.3 VisionMap A3 Edge camera and scanning system

- VisionMap System A3 Edge (Figure 1.3) from Israel is based on a double camera scanning system by which sequences of frames frames are imaged in the cross-track direction achieving very wide angle coverage of 100º FOV (field of view). The systems consist of dual CCD arrays with 300 mm lenses, a fast data compression system and a dual frequency GNSS system but no IMU is required. Given the unusual design, special fully automated software is required to process the data, which is also supplied by the company. The company claims that the advantages of this system are the higher productivity than other digital aerial cameras since it has much higher angle of field and very high scan rates.

1.3.2 Medium Resolution Digital Aerial Cameras

Medium resolution cameras, as the name suggests, are of lower resolution than the high resolution cameras, with most comprising a single area array of varying sizes for the capture of multi-spectral images. There are a number of these cameras on the market developed by different companies and they are undergoing considerable development with resolutions increasing as the development of chip technology improves. They are suitable for lower resolution aerial mapping or in combination with other forms of data, such as lidar.

1.3.3 General description of high spatial resolution near vertical aerial photogrammetric image acquisition

Most so-called ‘near vertical aerial photography’ is recorded with tilts from the vertical of less than 2˚. This has been traditional approach for film aerial photography and generally still applies for digital images. Such small tilts limit the distortions in the images which enable their processing to orthophotos to be less problematic. That is not to say that images with larger tilts cannot be processed to orthophotos, but the significant scale variations of photos with large tilts can lead to variations in the quality of the orthophoto, and large tilts can also cause important areas to be hidden behind buildings.

The theoretical assumptions made about the geometric processing of images are that all frame images are perspective projections. That is, all light rays forming an image pass through a single point, called a ‘perspective centre’. For linear array or pushbroom cameras the assumption of a perspective projection only applies along each scanline formed by each linear array. All aerial images are subject to certain distortions, due to tilts of the camera, elevation differences on the terrain for aerial images, deformations in the image formation process, particularly in the lens and atmospheric refraction which is a minor effect.

All photogrammetric measurements are based on overlapping images in order to obtain 3D object geometry. Typical overlaps on film images were 60% along track (forward overlap) and a minimum of 15% to 20% side overlap (sidelap) as shown in Figure 1.4. For the new era of digital imaging using area array cameras, the forward overlaps can be as large as 85%-90% and as high as 60% for sideways overlap between neighbouring strips of photography, also called 'sidelap'. For linear array cameras the 3 overlapping strips are acquired simultaneously. The side overlaps between strips may be 15% or larger.

Close range photographs are recorded with attitudes, ie tilts, designed to suit the particular application, but usually the optical axis of the camera will be directed approximately horizontally. The procedures for close range photography are therefore significantly different from aerial photography. Tilts may be much larger than 2˚ and the overlaps between photos may be up to 100%.

The original images recorded for film and digital photography are in the so-called negative plane as shown in Figure 1.4. The reproduction of the equivalent positive for a digital image is a trivial task. Therefore, all reference to images in these notes will assume the positive image is used.

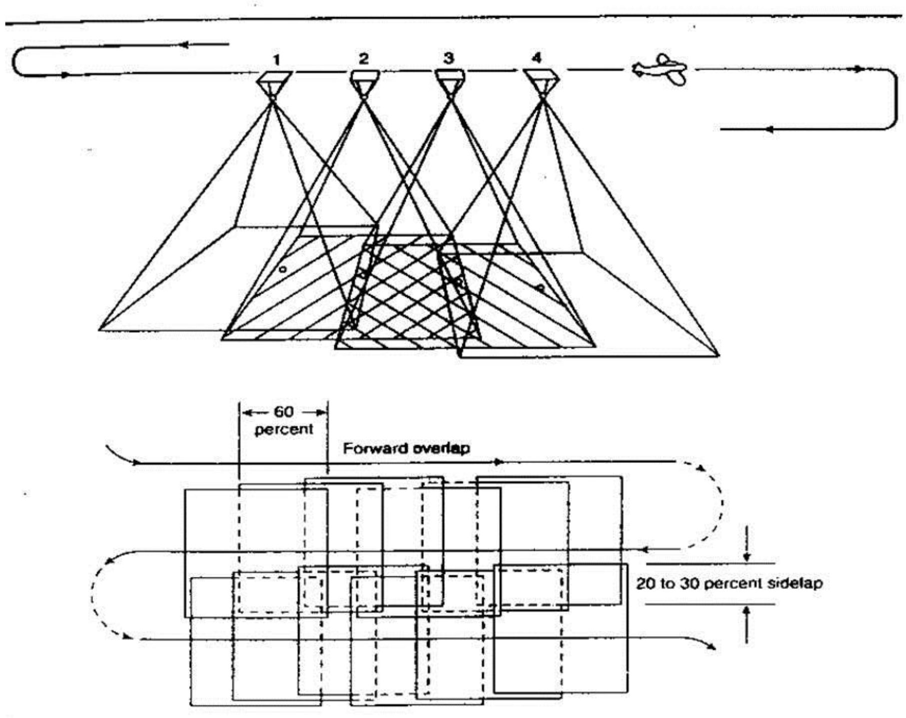


Figure 1.4 Configuration of aerial imaging with minimum overlap

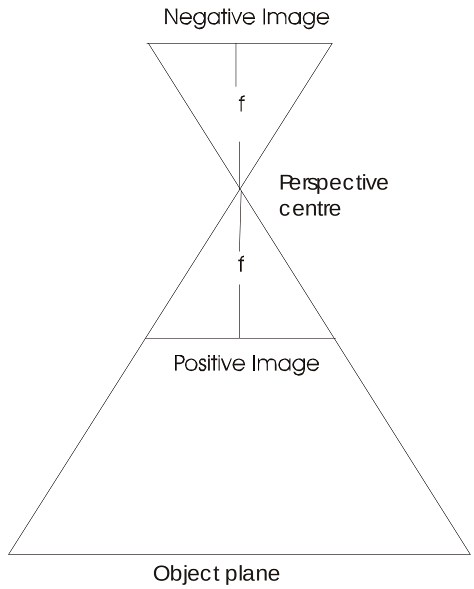


Figure 1.5 Geometric relationships between positive and negative image planes

The *principal distance* ‘f’, often called the *focal length*, defines the distance between the negative and positive image planes and the perspective centre (some textbooks use the symbol ‘c’ for the principal distance to avoid confusion with ‘f’ the focal length). As stated above the perspective centre defines the theoretical point in the camera, through which all light rays forming the image, are assumed to pass. The *principal point* is defined as the foot of the perpendicular from the perspective centre to the image plane. Hence the 3 components of what is known as the camera’s ‘*interior or inner orientation’* comprise x_0 and y_0 the x and y coordinates of the principal point and the principal distance ‘f’. (see Chapters 2, 3 and 6 for more details of their definitions) These components must be known before accurate measurement can be made from photographs.

1.3.4 Lens Distortion

All lenses will be subject to errors in image geometry due to design factors and manufacturing. The design of a lens is a compromise between the competing requirements of high image quality and near zero errors in the geometry of the image. Lens distortion is the deviation from a straight line path of the rays forming points in the images, which pass from the object through the perspective centre to the image plane. The largest component of lens distortion is radial to the principal point (Figure 1.6), while smaller tangential components may also occur in some lenses, but not those lenses specially designed for aerial photography. Aerial cameras will be subject to radial lens distortion of less than 5 µm, which will be symmetrical about the centre of the photograph. Recent research on digital aerial camera lenses has revealed distortions considerably less than 5 µm. Some 'non-metric' cameras used for close range photogrammetry may have lens distortions of the order of 100 µm. Lens distortions are determined as part of the process of camera calibration. It has been shown that radial-symmetric lens distortion in aerial lenses can be modelled by an odd-order polynomial of the form $dr=k_1r^3+k_2r^5+k_3r^7$, where dr is the radial distortion of a point on the image plane and r is the radial distance of the point measured from the principal point on the image plane, k_1, k_2 and k_3 are constants describing the characteristics of the distortion of a particular camera.

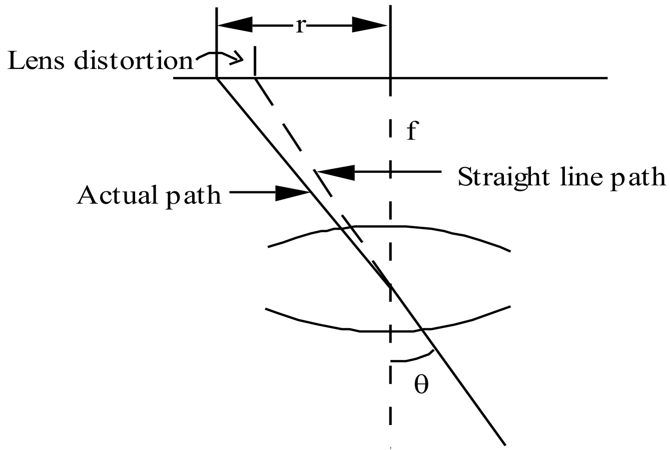
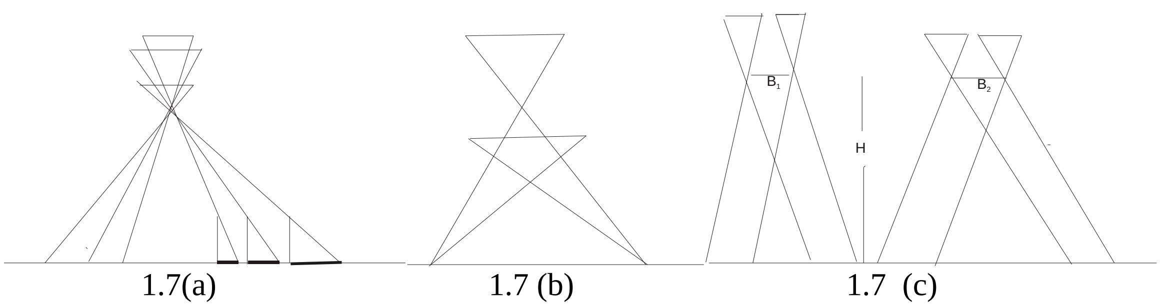


Figure 1.6 Radial lens distortion

1.3.5 Significance of the Angle of Field of a Camera

The angles of field of lens cones have a significant effect on the characteristics of photography acquired by cameras. The following general principles apply:

- The wider the angle of field, the greater the coverage for a given flying height - Figure 1.7a
- The same coverage, and hence the same scale of photography, can be obtained by varying the flying height for cameras with different angles of field. This means that for wider angle cameras, the flying height will be less - Figure 1.7b.



Figures 1.7a to 1.7c Examples of the relationships between the different camera lens cones

- The wider the angle of field, the greater will be the dead areas, ie obscured or occluded areas, hidden by buildings and steep terrain - Figure 1.7a
- The wider the angle of field, the larger the Base/Height (B/H) ratio - Figure 1.7c. In principle this will have an impact on the accuracy of height measurement.

1.3.6 Measurement of Exposure

Exposure is dependent on both the aperture in the lens and the exposure time. Doubling the aperture should enable halving the exposure time. The aperture is defined by an f/number, as a fraction of the focal length of the camera, as follows:

$$\text{Aperture f/number} = \frac{\text{Focal length (mm)}}{\text{Apertures stop diameter (mm)}} \qquad (1.1)$$

Increasing the aperture number, that is, reducing the size of the aperture, will reduce the effects of aberrations in the lens, and also increase the depth of field of the lens, ie the range over which objects are in focus. However, reducing the aperture size will also require an increase in exposure time, which may result in large image movement if either the object or camera is in motion, as is the case for aerial photography. To reduce the effects of image motion all modern digital aerial CCD frame cameras incorporate, *forward motion compensation* (FMC) by TDI (Transfer Delay and Integration). TDI is not possible with pushbroom cameras or CMOS sensor cameras, and hence other procedures need to be developed such as mechanical movement of the image plane. For close range photogrammetry, apertures would be selected to suit the application and if an object is in motion synchronized multiple cameras should be used.

1.3.7 Multi-Camera Systems

While multi-camera systems have existed for about 80 years, they have only come into regular use in modern aerial surveys over the past few years. The first modern multi-camera system was introduced by Pictometry more than 10 years ago. The system was based on 5 low cost cameras, one looking vertically and the other 4 looking obliquely in 4 directions at right angles as shown in the Figure 1.8. Subsequently other companies have developed their own version of multi-camera systems with high quality metric camera lenses, as for example the Vexcel Osprey, the IGI DigiCAM, comprising various options from one to five cameras (Penta DigiCAM), the Leica camera based on the RCD30 medium format camera and with up to 5 cameras.

Figure 1.8 Configuration of Pictometry imaging

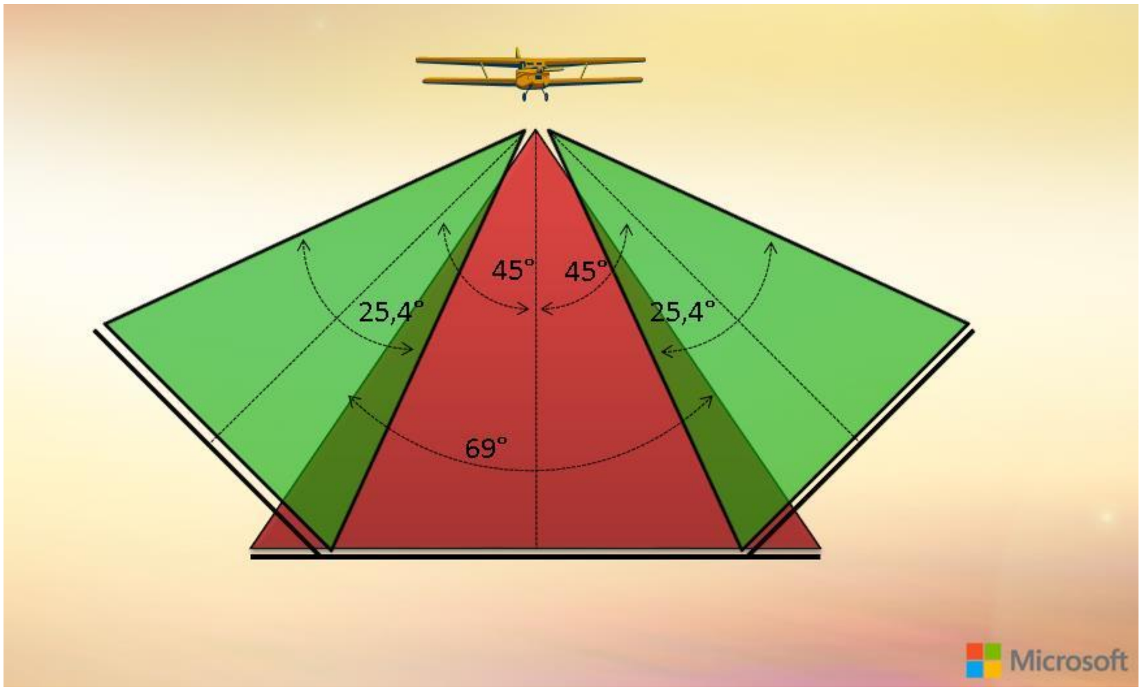


Figure 1.9. Plan view of overlaps between vertical and oblique images for Vexcel Osprey camera

The UltraCam Osprey camera for example, is designed with overlaps between the oblique and nadir images (Figure 1.9). All cameras are mounted rigidly on the platform with photogrammetric grade accuracy and are calibrated with respect to geometry and radiometry. These cameras are relatively new and therefore their applications are still being developed.

1.4 High Spatial Resolution Pushbroom Satellite Sensors

The design of satellite sensors is based on their specific purpose, but the recently developed so-called 'high spatial resolution' satellites are based on pushbroom sensors. They have resolutions or ground sampling distances (GSD) varying from about 2.5 m to about 0.3 m. Usually they detect both panchromatic images, which are black-and-white and cover the whole of the visible spectrum at the highest resolution, and up to 8 multispectral bands that have a GSD of 3 to 4 times larger than the panchromatic images. Stereo images are usually acquired by tilting the satellite forward and backwards during orbit. Most of these satellites are referred to as 'agile', since they can also acquire images by tilting sideways. Hence these satellites can acquire images within a day or so over anywhere on the earth. Typical currently available satellites with their respective ground sampling distances (GSD) are:

– IKONOS II (USA) launched in 1999 with 0.80 m panchromatic images and 3.2 m multispectral images
– Quickbird (USA) launched in 2002 with 0.60 m panchromatic images and 2.4m multispectral images; it is but now no longer operating but archive images are available
– WorldView-1 (USA) launched in 2007 with 0.50 m panchromatic images only
– CartoSat2B (India) launched in 2007 with 0.8 m panchromatic images
– GeoEye 1 (USA) launched in 2008, with 0.41 m panchromatic images and 1.65 m multispectral images

- WorldView-2 (USA) launched in 2009, with 0.4 m panchromatic images (originally supplied at 0.5 m resolution but currently available at 0.4 m resolution) and 1.85 m multi-spectral with 8 bands
- PLÉIADES (Europe) launched in 2011 with 50 cm Panchromatic and 2 m multi-spectral
- WorldView-3 (USA) launched in August 2014 with a GSD of 31 cm and 1.3 m multispectral.
- Terra Bella (formerly Skybox and now owned by Google) series of 21 satellites of which 2 are currently in orbit and all planned to be launched by end 2017. The satellites acquire panchromatic and multispectral images with <0.9 m spatial resolution and 1.1 m spatial resolution video images.
- Planet labs with over 100 microsatellites called 'Dove', with 3-5 m spatial resolution acquiring RGB using commercial grade CCD sensors. Their claim: 'In 2016 Planet Labs will have enough satellites in orbit to image the entire globe, every single day.'
- Urthecast has a sensor mounted on the International Space Station (ISS) can provide medium and high resolution imagery, with up to 75 cm pansharpened imagery available as well as video data.

The geometric processing of images from these satellites requires different procedures as will be described later.

1.5 MultiSpectral Sensing

Since the CCD technology used in pushbroom sensors is unable to detect electro-magnetic wavelengths longer than about 0.9 µm, other technologies and sensors are required to detect multiple bands with longer wavelengths for extraction of semantic information for remote sensing applications. These systems are referred to as either multispectral or hyperspectral sensors and usually described as 'whisk-broom' sensors although the designs of commercial satellites are 'commercial-in-confidence'. They are usually based on an optical scanning system, comprising a rotating mirror for aerial sensing and an oscillating mirror for satellite systems.

A typical configuration of these systems is based on either:

- **Across-track scanners** scan the Earth in a series of lines using a rotating mirror (A). The lines are oriented perpendicular to the direction of motion of the sensor platform. Successive scans build up a two-dimensional image of the Earth´s surface. The incoming reflected or emitted radiation is separated into spectral components that are detected independently and dispersed into their constituent wavelengths. A bank of internal detectors (B), each sensitive to a specific range of wavelengths between 0.4 µm at the blue end of the visible spectrum, to about 15µm in the thermal region of the spectrum, detects and measures the energy for each spectral band and then, as an electrical signal, they are converted to digital data and recorded for subsequent computer processing. The width of the bands varies according to the system design and wavelength being recorded. They may be of the order of several µm for thermal sensors to as little as 1-2 nm for hyperspectral systems, which may detect and record hundreds of very narrow bands. The IFOV (C) of the sensor and the altitude of the platform determine the ground resolution cell viewed (D), and thus the spatial resolution. The angular field of view (E) is the sweep of the mirror, measured in degrees, used to record a scan line, and determines the width of the imaged swath (F). Because the distance from the sensor to the target increases towards the edges of the swath, the ground resolution cells also become larger and introduce geometric distortions to the images. Also, the length of time the IFOV "sees" a ground resolution cell as the rotating mirror scans (called the dwell time), is generally short which influences the design of the spatial, spectral, and radiometric resolution of the sensor.

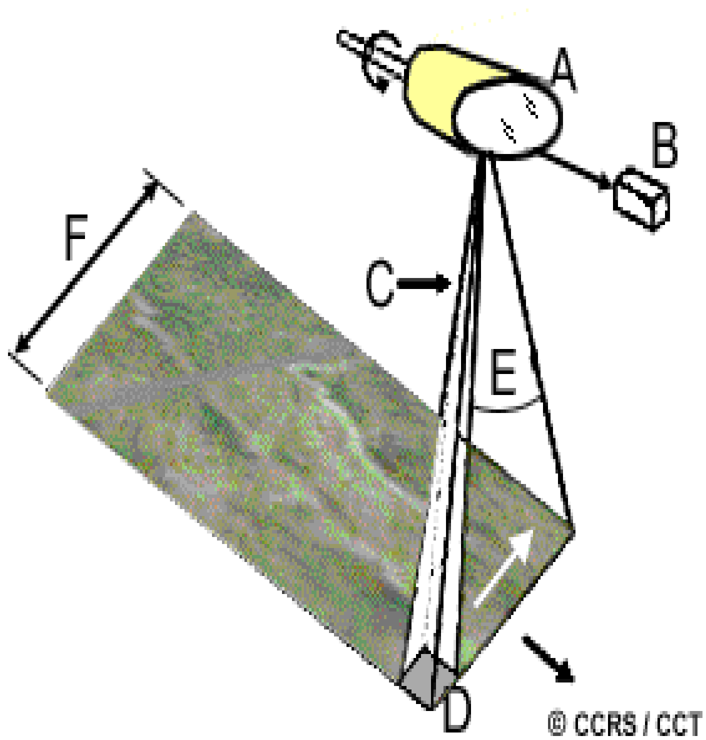


Figure 1.10 Multispectral Scanner Using a Scanner Mirror

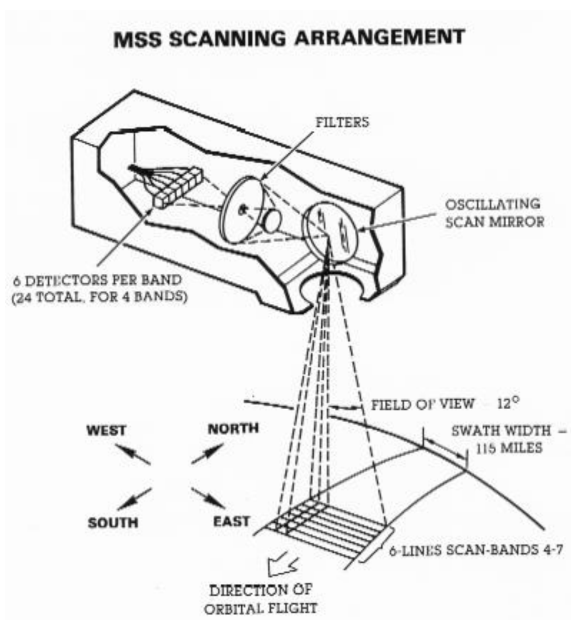


Figure 1.11 Oscillating mirror scanner used in Landsat satellites

- Satellite systems, such as a number of Landsat satellites, are usually based on an oscillating mirror as shown in Figure 1.11. The swath width of an oscillating mirror scanner can be limited to 100 km or so, based on small rotations of the mirror, and hence is preferred over a rotating mirror which would record a very large part of the globe from space.

1.7 Radar Sensors

Airborne or spaceborne imaging radar sensors are active microwave remote sensing systems which emit radiation from an antenna, and record the time of transmission for the radiation to be returned to the antenna. They primarily measure angles and distances based on the time of travel the reflected radiation, T. The radar beam is emitted sideways from the platform, approximately normal to the direction of flight, at an inclination to the horizontal, as shown in Figure 1.12.

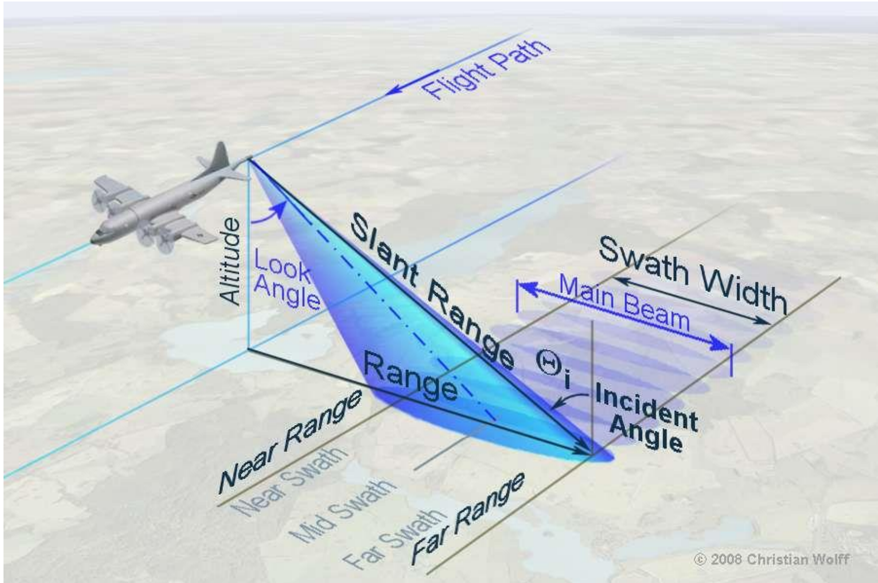


Figure 1.12 Data Acquisition by Radar System

The range, R, is therefore derived from the formula:

$$\mathbf{R=cT/2} \qquad (1.2)$$

where c is the velocity of the electro-magnetic radiation in the atmosphere. The range resolution, at right angles to the flight direction, is a function of the *pulse repetition frequency* (PRF) of the radar signal transmission. The azimuth resolution, in the direction of flight, is a function of the length of the antenna. To achieve a small azimuth resolution of the image, it is necessary to use an extremely long antenna (several km). A *synthetic aperture radar*, or SAR, overcomes this problem of achieving a suitable spatial resolution in the azimuth direction by synthesising a very long antenna, by processing the reflected signals that are acquired as the platform progresses. The azimuth resolution of SAR images can be shown to be approximately equal to d/2, where d is the actual length of the antenna on the platform. This means that the resolution of the images will decrease ie, improve as the antenna decreases in size. In addition, the azimuth resolution is independent of the elevation of the platform and the frequency of propagation. The limits of azimuth resolution are constrained, because the complexity of the radar system. Data storage and processing requirements all increase with increasing range and wavelength, while power requirements increase sharply as the antenna decreases in length.

Radar images are affected by geometric errors, which are functions of the combination of the elevation angle of the signal and variations in the elevations in the terrain. These errors are layover, foreshortening and shadow, as shown in Figure 1.13. Layover is caused by the imaging characteristics of radar, since ranges (distances) are measured from the antenna to the terrain. Elevated points are closer to the antenna than points below them and these points will therefore be imaged closer to the nadir point in the image. This effect will increase as the elevation or look angle of the emitted radiation decreases. Foreshortening will occur when slopes in the terrain facing the antenna are compressed in size due to the effects of layover. Shadows are image voids caused by certain areas being hidden from the radar beam, because of the intervening terrain features. In addition to errors caused by terrain elevations, the continuous process of data acquisition of SAR data will result in geometric distortions caused by variations in the platform attitude during flight.

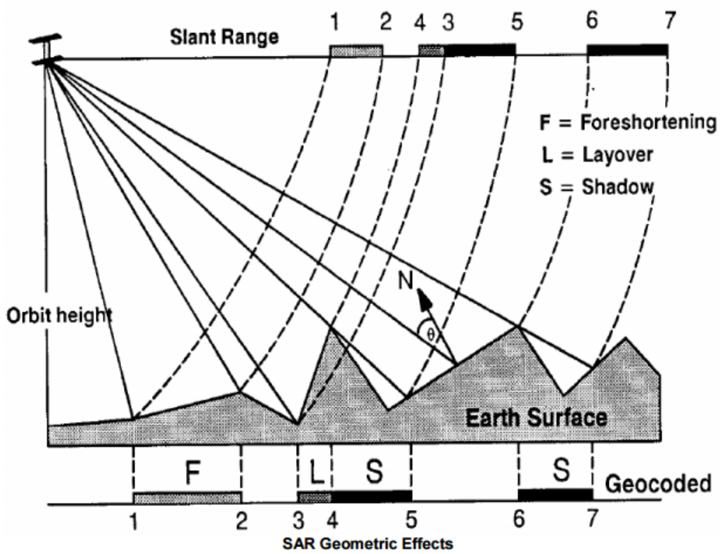


Figure 1.13 Geometric Distortions in SAR Data

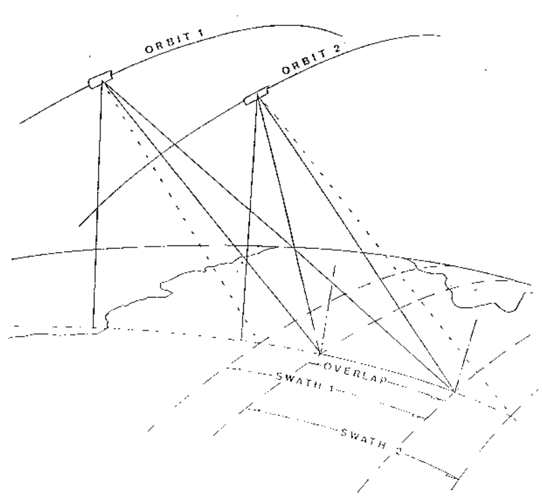


Figure 1.14 Same–side data acquisition for stereo observation of radar images

1.7.1 Overlapping Radar Images

Overlapping images for elevation computations are derived by the acquisition of two parallel passes as show in Figure 1.14, which demonstrates the so-called 'same-side' stereo configuration. That is, the antennas view the terrain from the same side of the platform. Opposite side configuration is also possible but there are limitations in the suitability of this configuration for computation of elevations because of the large geometric distortions as described above. The accuracy of elevation computation from overlapping radar images is usually poor. A more accurate method being developed is referred to as interferometric radar.

1.7.2 Interferometric SAR (InSAR and also referred to as IfSAR)

A SAR image of a scene comprises amplitude and phase information. In Figure 1.15, two antennas A_1 and A_2 with a baseline length B, record the echoes of the signal emitted by one of the antennas. The range distance from an illuminated point on the ground to antenna A_1 is r, while $r + \delta r$ is the distance to antenna A_2 from the same point. The difference in phases in wavelengths, between the signals received at the two antennas can be used to determine the difference in range δr and hence terrain elevations with high accuracy. After registering the two images, the phases are calculated and differenced on a pixel by pixel basis, resulting in a phase difference image or interferogram.

Accuracies of elevations determined by interferometric SAR depend on the parameters of the radar system and can be better than 0.5 metre for low wavelength airborne radar systems. Accuracies of the order of several metres are achievable with spaceborne systems. An approach called differential InSAR is based on the acquisition of SAR images in two or more epochs and can be used for monitoring small changes in elevation, such as those that occur due to earthquakes and mine subsidence. Accuracies of differential InSAR can be of the order of 1 cm, even when the images are recorded from space.

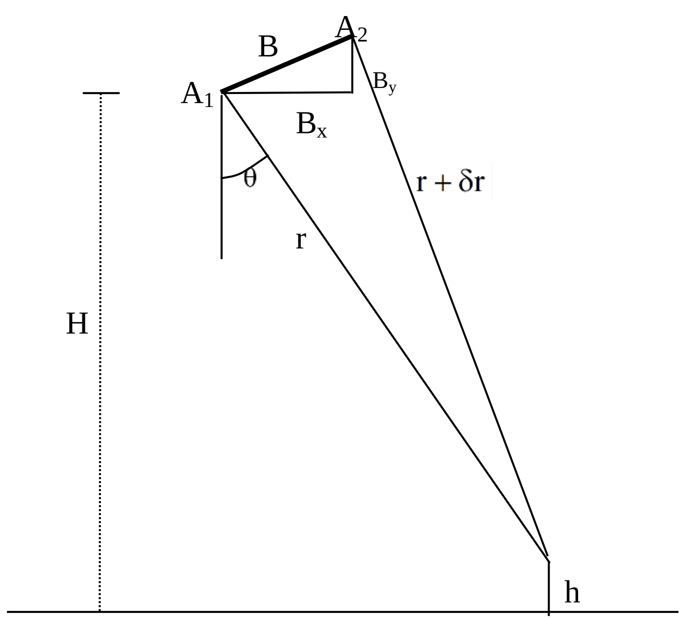


Figure 1.15 A schematic diagram of InSAR.

1.8 Airborne Lidar or Airborne Laser Scanning (ALS)

In airborne lidar (**Li**ght **D**etection **A**nd **R**anging also written as LiDAR) or airborne laser scanning (ALS), a laser scans the terrain surface normal to the flight direction of an aircraft AS SHOWN IN Figure 1.16. The measured distance from the aircraft to visible points on the terrain surface will enable the position and elevation of points to be determined. A lidar system includes the following equipment:

- The laser scanning normal to the flight direction for which the range to the object and rotation angle of the scanner are determined
- GNSS equipment to determine the location of the aircraft based on kinematic measurements
- IMU to continuously determine the tilts of the aircraft.

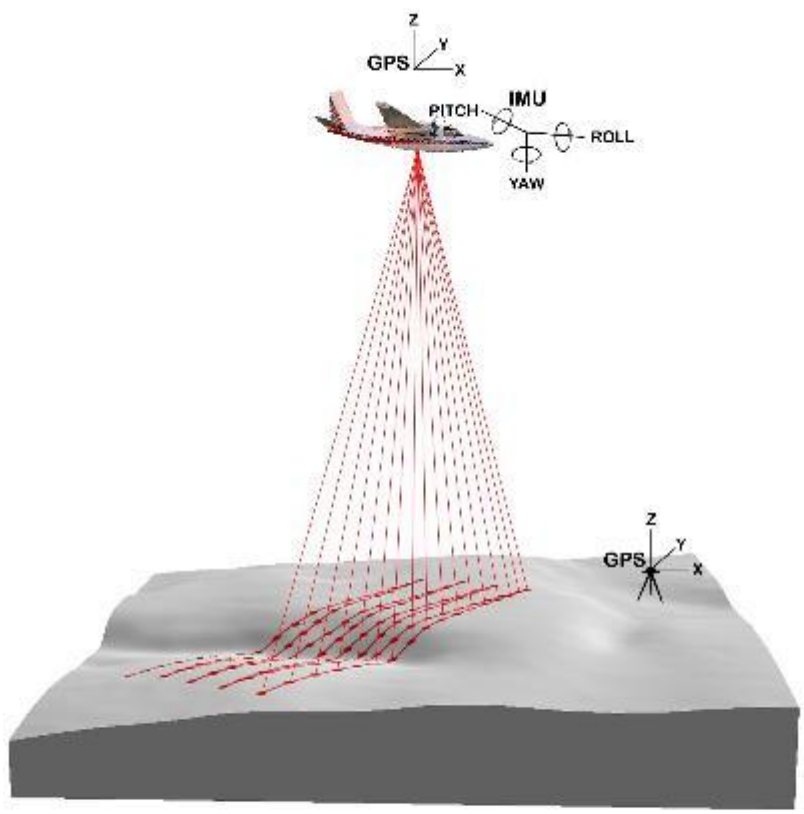


Figure 1.16 Airborne lidar system

Lidar systems acquire a dense set of elevation posts (XYZ coordinates), referred to as a *point cloud*, at a separation typically of 1 m or less for modern lidar systems, that represent a digital surface model (DSM) of the visible terrain, that is, objects such as buildings and trees, but also the terrain surface if the laser beam penetrates the vegetation. The accuracy of the elevation posts is of the order of 10-20 cm, although tests have shown that accuracies of interpolated hard surfaces better than 5 cm are achievable. The separation of the posts will depend on the configuration of the lidar equipment and the scanning frequency, which is increasing as the systems are developed further. This technology is also referred to as 'linear lidar' to differentiate them from single photon lidar (SPL) and Geiger systems as described below.

Some lidar systems can register multiple returns or echoes of the laser beam, but most systems will register, as a minimum the *first* and the *last pulses*. For example, if the laser beam hits a tree, a part of the laser beam will be reflected by the canopy, resulting in the returned signal being registered by the sensor as the *first pulse*. The rest of the beam may penetrate the canopy and, thus be reflected from further below the top of the tree, maybe even by the soil. The *last pulse* registered by the sensor corresponds to the lowest point from which the signal was reflected. In certain cases, the difference in elevation between the first and last pulses can be assumed to measure the heights of trees or buildings.

Along with the time of transmission of the signal from the sensor to the terrain and back to the sensor, the *intensity* of the returned laser beam is also registered by lidar systems. Lidar systems typically operate in the infrared part of the electromagnetic spectrum and therefore the intensity can be interpreted as an infrared (IR) image. However, this intensity image is usually under-sampled and thus very noisy, because the footprint of the lidar is about 0.3 m-0.5 m and the average sampling point distance is 0.3 m to 1 m apart. As well as the laser data, images of the terrain surface may also be recorded by a separate medium or high resolution digital camera. These images may be used to identify the location of points on the terrain surface. The combination of colour and the IR as multi-spectral images can provide valuable information for information extraction of the terrain surface. Multi-spectral lidar systems have now been developed incorporating 2 or 3 lidar beams with different wavelengths.

Technological advances have resulted in new systems being developed, referred to as single photon lidar (SPL) and Geiger systems, which enable the collection of data with much higher point densities. They offer better use of the photons generated by the laser source, resulting in a dense point cloud from the same or a less efficient laser source. These systems are not available on the market year, but they are likely to be available in a year or so.

Typical applications of lidar data may include:

- DEMs of the bare earth surface
- Beach erosion studies
- Infrastructure analysis
- Flood risk analysis, flood simulation, and drainage design
- Ground subsidence
- Visibility analysis
- Telecommunications planning
- Noise propagation studies
- Volume change monitoring
- Buildings extraction for 3D city models
- Forest analysis

The economics of lidar equipment require it to be used over large areas, and hence GBytes of data are likely to be acquired in a single mission (250,000 points may be recorded in a few seconds). Therefore, it is essential that automatic processes are developed that enable the extraction of information from the lidar data. There are described in more details later in these notes.

A Course Material on

Remote Sensing Techniques and GIS

By

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OBJECTIVE

Tointroducethestudentstothebasicconcepts andprinciples ofvariouscomponents ofremote sensing.ToprovideanexposuretoGISand itspracticalapplicationsincivilengineering.

UNITI EMRANDITSINTERACTIONWITHATMOSPHERE&EARTH MATERIAL 9

Definitionofremotesensinganditscomponents–Electromagneticspectrum –wavelength regionsimportanttoremotesensing –Wavetheory,Particle theory,Stefan-Boltzman and Wein's Displacement Law – Atmospheric scattering,absorption – Atmospheric windows – spectralsignatureconcepts –typicalspectralreflectivecharacteristicsofwater,vegetationand soil.

UNITII PLATFORMSANDSENSORS 9

Types ofplatforms– orbittypes,Sun-synchronousandGeosynchronous–Passive andActive sensors–resolutionconcept–Payload descriptionofimportantEarthResources and Meteorological satellites–AirborneandspaceborneTIRand microwavesensors.

UNITIII IMAGEINTERPRETATION ANDANALYSIS 9

TypesofDataProducts–typesofimageinterpretation–basicelementsofimageinterpretation -visualinterpretationkeys–DigitalImageProcessing–Pre-processing–imageenhancement techniques–multispectral imageclassification –Supervisedandunsupervised.

UNITIV GEOGRAPHICINFORMATIONSYSTEM 9

Introduction–Maps–Definitions–Mapprojections–typesofmapprojections–mapanalysis– GISdefinition –basiccomponentsofGIS–standardGISsoftwares–Data type–Spatialand non-spatial (attribute)data–measurementscales–DataBaseManagementSystems(DBMS).

UNITV DATAENTRY,STORAGEANDANALYSIS 9

Datamodels–vectorandrasterdata–datacompression–datainputbydigitizationand scanning–attributedataanalysis–integrateddataanalysis–Modeling inGISHighway alignmentstudies–LandInformationSystem.

TOTAL:45PERIODS

TEXTBOOKS

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CHAPTER 1

UNIT I EMR AND ITS INTERACTION WITH ATMOSPHERE & EARTH MATERIAL

1.1 DEFINITION AND PROCESS OF REMOTE SENSING

1.1.1INTRODUCTION

Now-a-days the field of Remote Sensing and GIS has become exciting and glamorous with rapidly expanding opportunities. Many organizations spend large amounts of money on these fields. Here the question arises why these fields are so important in recent years. Two main reasons are there behind this. 1) Now-a-days scientists, researchers, students, and even common people are showing great interest for better understanding of our environment. By environment we mean the geographic space of their study area and the events that take place there. In other words, we have come to realize that geographic space along with the data describing it, is part of our everyday world; almost every decision we take is influenced or dictated by some fact of geography. 2) Advancement in sophisticated space technology (which can provide large volume of spatial data), along with declining costs of computer hardware and software (which can handle these data) has made Remote Sensing and G.I.S. affordable to not only complex environmental / spatial situation but also affordable to an increasingly wider audience.

1.2 REMOTE SENSING AND ITS COMPONENTS:

Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information." In much of remote sensing, the process involves an interaction beteen incident adiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. However that remote sensg also involves the sensing of emitted energy and the use of non-imaging sensors.

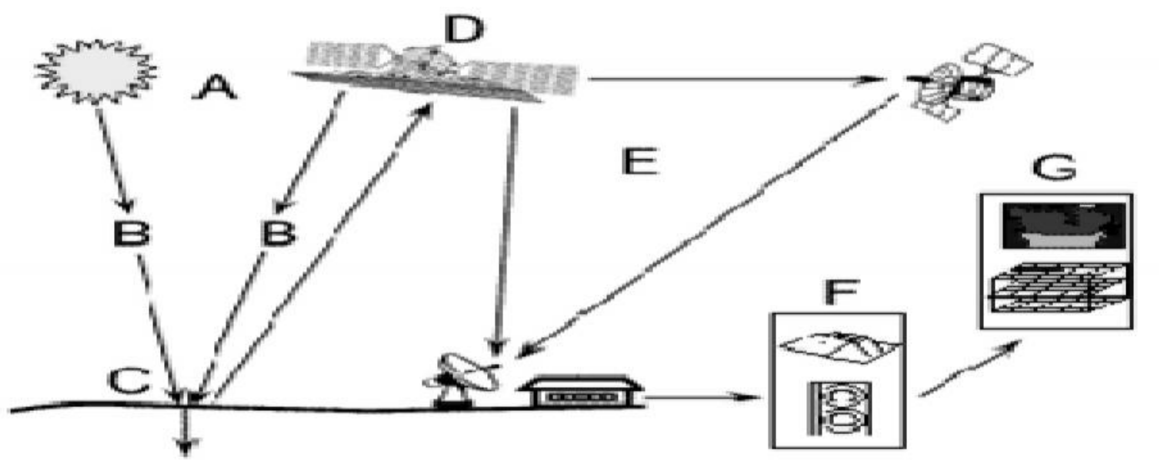


Fig 1.1- Components of Remote Sensing

1. Energy Source or Illumination (A) – the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

2. Radiation and the Atmosphre (B) – as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

3. Interaction with the Target (C) - once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.

4. Recording of Energy by the Sensor (D) - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

5. Transmission, Reception, and Processing (E) - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

6. Interpretation and Analysis (F) - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.

7. Application (G) - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

HISTRY OF REMOTE SENSING:

- 1839 - first photograph
- 1858 - first photo from a balloon
- 1903 - first plane
  - 1909 first photo from a plane
- 1903-4 -B/W infrared film
- WW I and WW II
- 1960 - space

1.3 ELECTROMAGNETIC SPECTRUM

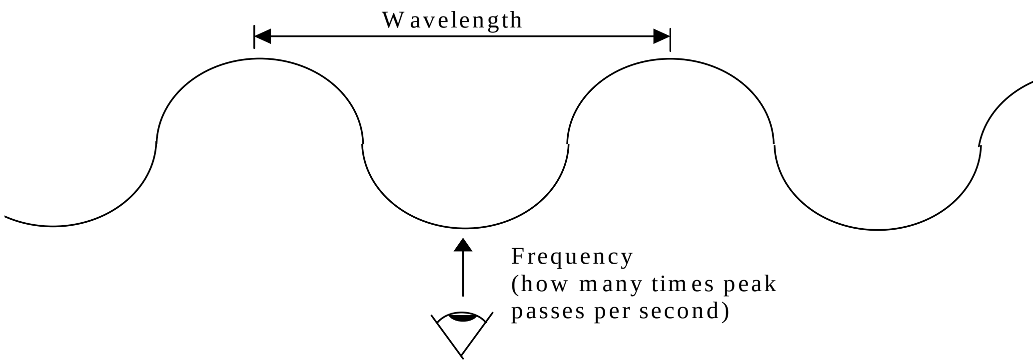
The first requirement for remote sensing is to have an **energy source to illuminate the target** (unless thesensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation. All electromagnetic radiation has fundamental properties and behaves in predictable ways according to the basicsof wave theory.

Electromagnetic radiation consists of an electrical field (E) which varies inmagnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c). Two characteristics of electromagnetic radiation are particularly important to understand remote sensing. These are the **wavelength and frequency.**

Electromagnetic radiation (EMR) as an electromagnetic wave that travels through space at the speed of light C which is $3x10^8$ meters per second.

Theoretical model of random media including the anisotropic effects, random distribution discrete scatters, rough surface effects, have been studied for remote sensing with electromagnetic waves.

Light - can be thought of as a wave in the 'electromagnetic field' of the universe



A wave can be characterized by its wavelength or its frequency

Fig 1.2 – Wavelength and frequency

The wavelength is the length of one wave cycle, which can be measured as the distance between successive wave crests. Wavelength is usually represented by the Greek letter lambda (λ). Wavelength is measured in metres (m) or some factor of metres such as **nanometres** (nm, 10-9 metres), **micrometres** (μm, 10-6 metres) (μm, 10-6 metres) or centimetres (cm, 10-2 metres). Frequency refers to the number of cycles of a wave passing a fixed point per unit of time. Frequency is normally measured in **hertz** (Hz), equivalent to one cycle per second, and various multiples of hertz.

Wavelength and frequency are related by the following formula:

$$c=\lambda v$$

where:

λ = wavelength (m)
v= frequency (cycles per second, Hz)
c =speed of light ($3x10^8$ m/s)

Therefore, the two are inversely related to each other. The shorter the wavelength, the higher the frequency. The longer the wavelength, the lower the frequency. Understanding the characteristics of electromagnetic radiation in terms of their wavelength and frequency iscrucial to understanding the information to be extracted from remote sensing data.

The electromagnetic spectrum ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves). There are several regions of the electromagnetic spectrum which are useful for remote sensing.

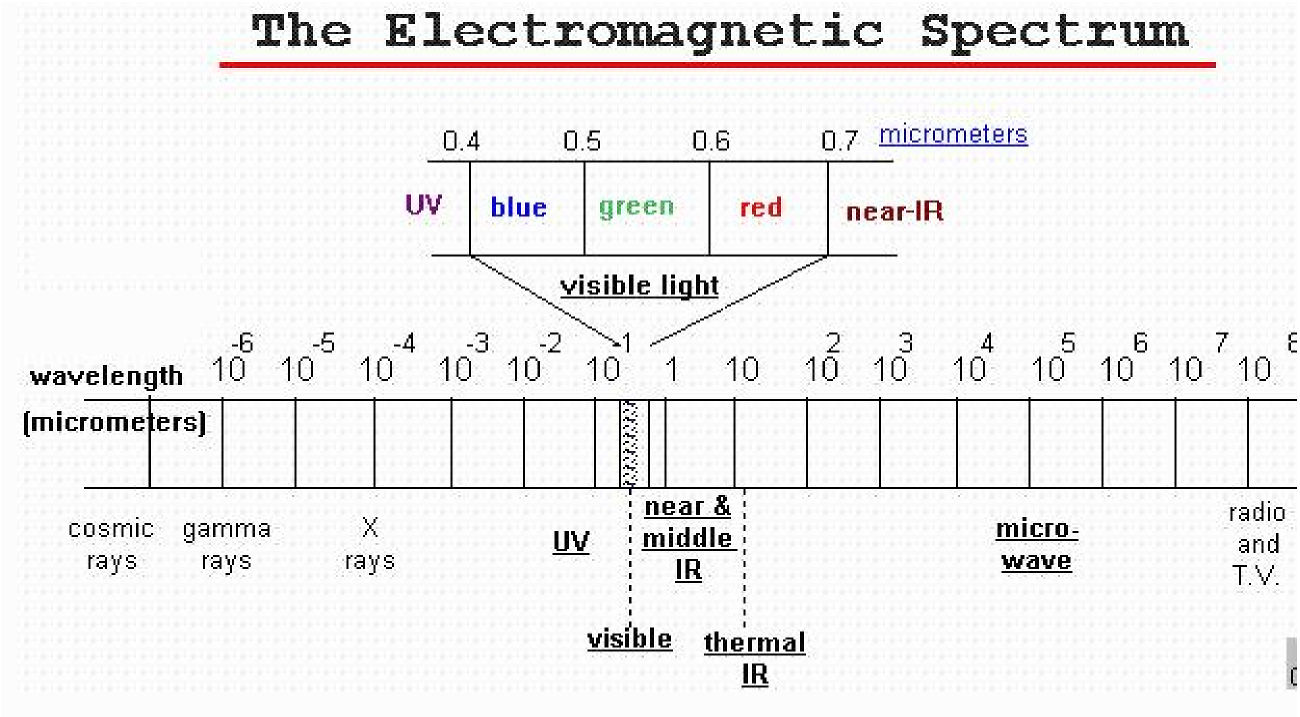


Fig 1.3 – Electromagnetic Spectrum

1.4 WAVELENGTH REGIONS IMPORTANT TO REMOTE SENSING:

1.4.1 Ultraviolet or UV

For the most purposes ultraviolet or UV of the spectrum shortest wavelengths are practical for remote sensing. This wavelength beyond the violet portion of the visible wavelengths hence it name. Some earth surface materials primarly rocks and materials are emit visible radiation when illuminated by UV radiation.

1.4.2 Visible Spectrum

The light which our eyes - our "remote sensors" - can detect is part of the **visible spectrum**. It is important to recognize how small the visible portion is relative to the rest of the spectrum. There is a lot of radiation around us which is"invisible" to our eyes, but can be detected by other remote sensing instruments and used to our advantage. The visible wavelengths cover a range from approximately 0.4 to 0.7 µm. The longest visible wavelength is red and the shortest is violet. Common wavelengths of what we perceive as particular colours from the visible portion of the spectrum are listed below. It isimportant to note that this is the only portion of the spectrum we can associate with the concept of **colours**.

Violet: 0.4 -0.446 µm

Blue: 0.446 -0.500 µm

Green: 0.500 -0.578 µm

Yellow: 0.578 -0.592 µm

Orange: 0.592 -0.620 µm

Red: 0.620 -0.7 µm

Blue, **green**, and **red** are the **primary colours** or wavelengths of the visible spectrum. Theyare defined as such because no single primary colour can be created from the other two, but all other colours can be formed by combining blue, green, and red in various proportions. Although we see sunlight as a uniform or homogeneous colour, it is actually composed of various wavelengths of radiation in primarily the ultraviolet, visible and infrared portions of the spectrum. The visible portion of this radiation can be shown in its component colours when sunlight is passed through a **prism**, which bends the light in differing amounts according to wavelength.

1.4.3 Infrared (IR)

The next portion of the spectrum of interest is the infrared (IR) region which covers the wavelength range from approximately 0.7 µm to 100 µm more than 100 times as wide as the visible portion. The infrared can be divided into 3 categories based on their radiation properties-the reflected near- IR middle IR and thermal IR.

The reflected near IR covers wavelengths from approximately 0.7 µm to 1.3 µm is commonly used to expose black and white and color-infrared sensitive film.

The middle-infrared region includes energy with a wavelength of 1.3 to 3.0 µm.

The thermal IR region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat. The thermal IR covers wavelengths from approximately 3.0 µm to 100 µm.

Microwave

This wavelength (or frequency) interval in the electromagnetic spectrum is commonly referred to as a band, channel or region.The major subdivision

The portion of the spectrum of more recent interest to remote sensing is the microwave region from about 1 mm to 1 m. This covers the longest wavelengths used for remote sensing. The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcasts.

Region	Wavelength	Remarks
Gamma ray	<0.03 nm	Incoming radiation is completely absorbed by the upper atmosphere and is not available for remote sensing.
X-ray	0.03 to 3.0 nm	Completely absorbed by atmosphere. Not employed in remote sensing.
Ultraviolet	0.3 to 0.4 μm	Incoming wavelengths less than 0.3 μm are completely absorbed by ozone in the upper atmosphere.
Photographic UV band	0.3 to 0.4 μm	Transmitted through atmosphere. Detectable with film and photodetectors, but atmospheric scattering is severe
Visible	0.4 to 0.7 μm	Imaged with film and photodetectors. Includes reflected energy peak of earth at 0.5 μm.
Infrared	0.7 to 1.00 μm	Interaction with matter varies with wave length. Atmospheric transmission windows are separated.
Reflected IR band	0.7 to 3.0 μm	Reflected solar radiation that contains information about thermal properties of materials. The band from 0.7 to 0.9 μm is detectable with film and is called the photographic IR band.
Thermal IR	3 to 5 μm band	Principal atmospheric windows in the 8 to 14 μm thermal region. Images at these wavelengths are acquired by optical mechanical scanners and special vidicon systems but not by film. Microwave 0.1 to 30 cm longer wavelengths can penetrate clouds, fog, and rain. Images may be acquired in the active or passive mode.
Radar	0.1 to 30 cm	Active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
Radio	>30 cm	Longest wave length portion of electromagnetic spectrum. Some classified radars with very long wavelengths operate in this region.

1.5 WAVE THEORY AND PARRTICAL THEORY

Light can exhibit both a wave theory, and a particle theory at the same time. Much of the time, light behaves like a wave. Light waves are also called electromagnetic waves because they are made up of both electric (*E*) and magnetic (*H*) fields. Electromagnetic fields oscillate perpendicular to the direction of wave travel, and perpendicular to each other. Light waves are known as transverse waves as they oscillate in the direction traverse to the direction of wave travel.

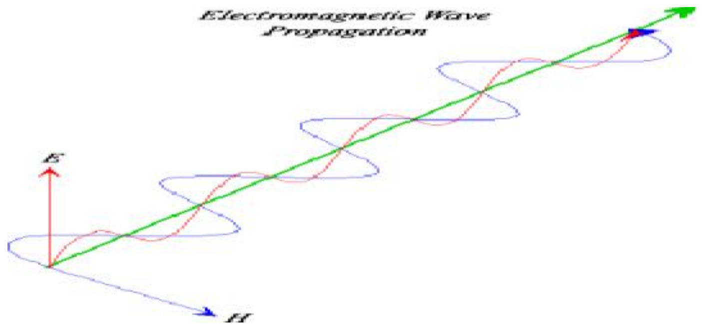


Fig 1.4 – Electromagnetic propagation

Waves have two important characteristics - wavelength and frequency.

The sine wave is the fundamental waveform in nature. When dealing with light waves, we refer to the sine wave. The period (*T*) of the waveform is one full 0 to 360 degree sweep. The relationship of frequency and the period is given by the equation:

$f = 1 / T$

$T = 1 / f$

The waveforms are always in the time domain and go on for infinity.

The speed of a wave can be found by multiplying the two units together. The wave's speed is measured in units of length (distance) per second:

Wavelength x Frequency = Speed

As proposed by Einstein, light is composed of photons, a very small packets of energy. The reason that photons are able to travel at light speeds is due to the fact that they have no mass and therefore, Einstein's infamous equation - $E=MC^2$ cannot be used. Another formula devised by Planck, is used to describe the relation between photon energy and frequency - *Planck's Constant* (*h*) - 6.63×10^{-34} Joule-Second. $E = hf$ (or) $E = hc/ɣ$

E is the photonic energy in Joules, *h* is Planks constant and *f* is the frequency in Hz.

1.5.1 PARTICAL THEORY

The basic idea of quantum theory is that radiant energy is transmitted inindivisible packets whose energy is given in integral parts, of size hv, where h is Planck's constant = 6.6252 x 10-34 J - s, and v is the frequency of the radiation. These are called quanta or photons.

The dilemma of the simultaneous wave and particle waves of electromagneticenergy may be conceptually resolved by considering that energy is not supplied continuously throughout a wave, but rather that it is carried by photons. The classical wave theory does not give the intensity of energy at a point in space, but gives the probability of finding a photon at that point. Thus the classical concept of a wave yields to the idea that a wave simply describes the probability path for the motion of the individual photons.

The particular importance of the quantum approach for remote sensing is thatit provides the concept of discrete energy levels in materials. The values and arrangement of these levels are different for different materials. Information about a given material is thus available in electromagnetic radiation as a consequence of transitions between these energy levels. A transition to a higher energy level is caused by the absorption of energy, or from a higher to a lower energy level is caused by the' emission of energy. The amounts of energy either absorbed or emitted correspond precisely to the energy difference between the two levels involved in the transition. Because the energy levels are different for each material, the amount of energy a particular substance can absorb or emit is different for that material from any other materials. Consequently, the position and intensities of the bands in the spectrum of a given material are characteristic to that material.

1.6 STEFAN–BOLTZMANN LAW

Stefan–Boltzmann law, also known as **Stefan's law**, describes the power radiated from a black body in terms of itstemperature. Specifically, the Stefan–Boltzmann law states that the total energy radiated per unit surface area of a black body across all wavelengths per unit time (also known as the black-body *radiant exitance* or *emissive power*), $j^{\star}$, is directlyproportional to the fourth power of the black body's thermodynamic temperature *T*:

$$j^{\star} = \sigma T^{4}.$$

1. 7 WIEN'S DISPLACEMENT LAW

Wien's displacement law states that the black body radiation curve for different temperatures peaks at a wavelength inversely proportional to the temperature. The shift of that peak is a direct consequence of the Planck radiation law which describes the spectral brightness of black body radiation as a function of wavelength at any given temperature. However it had been discovered by Wilhelm Wien several years before Max Planck developed that more general equation, and describes the entire shift of the spectrum of black body radiation toward shorter wavelengths as temperature increases.

Formally, Wien's displacement law states that the spectral radiance of black body radiation per unit wavelength, peaks at the wavelength λ_{max} given by:

$$\lambda_{\max} = \frac{b}{T}$$

where *T* is the absolute temperature in degrees kelvin. *b* is a constant of proportionality called *Wien's displacement constant*, equal to $2.8977721(26) \times 10^{-3}$ m K.[1], or more conveniently to obtain wavelength in microns, b≈2900 μm K. If one is considering the peak of black body emission per unit frequency or per proportional bandwidth, one must use a different proportionality constant. However the form of the law remains the same: the peak wavelength is inversely proportional to temperature (or the peak frequency is directly proportional to temperature).

Wien's displacement law may be referred to as "Wien's law", a term which is also used for the Wien approximation.

1.8 ENERGY INTERACTIONS WITH THE ATMOSPHERE

Before radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere. Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of scattering and absorption .

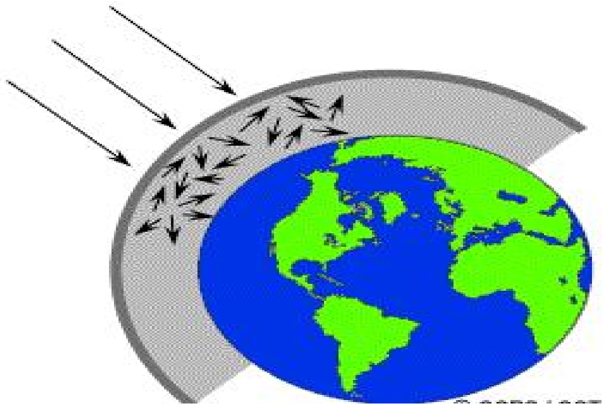


Fig 1.5 Energy Interaction with Atmosphere

1.8.1 SCATTERING

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere. There are three (3) types of scattering which take place.

1.8.2 RAYLEIGH SCATTERING

Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation. These could bearticles such as small specks of dust or nitrogen and oxygen molecules. Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths. Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere.The fact that the sky appears "blue" during the day is because of this phenomenon. As sunlight passes through the atmosphere, the shorter wavelengths (i.e. blue) of the visible spectrum are scattered more than the other (longer) visible wavelengths. At **sunrise and sunset** the light has to travel farther through the atmosphere than at midday and the scattering of the shorter wavelengths is more complete; this leaves a greater proportion of the longer wavelengths to penetrate the atmosphere.

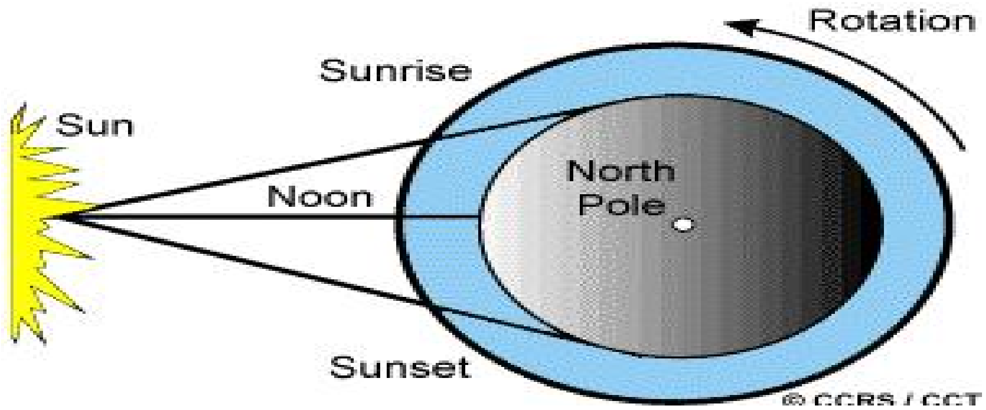


Fig 1.6 Raleigh Scattering

1.8.3ABSORPTION

Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, and water vapor are the three main atmospheric constituents which absorb radiation. **Ozone** serves to absorb the harmful (to most living things) ultraviolet radiation for the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight. **Carbon dioxide** referred to as a greenhouse gas. This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere. Water vapour in the atmosphere absorbs much of the incoming longwave infrared and shortwave microwave radiation (between 22μm and 1m). The presence of water vapour in the lower atmosphere varies greatly from location to location and at different times of the year. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high concentrations of water vapour (i.e. high humidity).

1.8.4 MIE SCATTERING

Mie scattering occurs when the particles are just about the same size as the wavelength of the radiation. Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates when cloud conditions are overcast.

The final scattering mechanism of importance is called **nonselective scattering**. This occurs when the particles are much larger than the wavelength of the radiation.

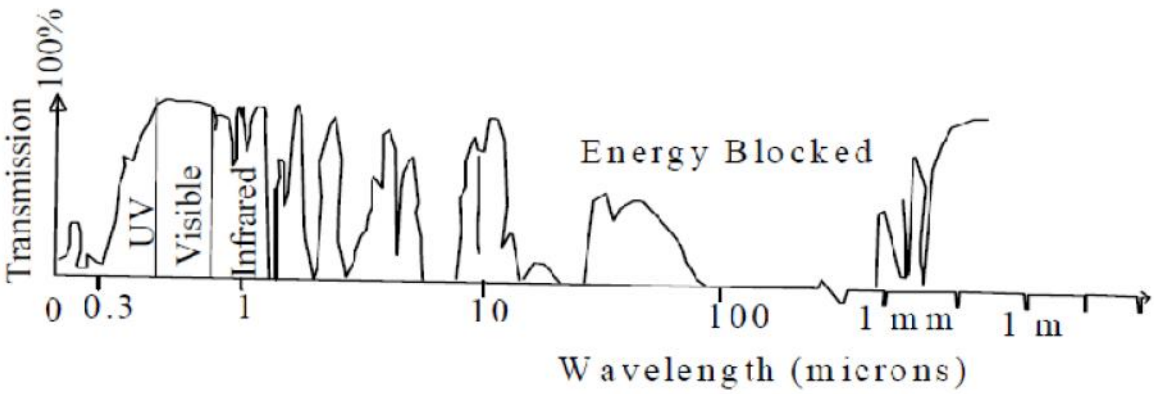
Water droplets and large dust particles can cause this type of scattering. Nonselective scattering gets its name from the fact that all wavelengths are scattered about equally. This type of scattering causes fog and clouds to appear white to our eyes because blue, green, and red light are all scattered in approximately equal quantities (blue+green+red light = white light).

1.9 ATMOSPHERIC WINDOWS

While EMR is transmitted from the sun to the surface of the earth, it passes through the atmosphere. Here, electromagnetic radiation is scattered and absorbed by gases and dust particles. Besides the major atmospheric gaseous components like molecular nitrogen and oxygen, other constituents like water vapour, methane, hydrogen, helium and nitrogen compounds play important role in modifying electro magnetic radiation. This affects image quality. Regions of the electromagnetic spectrum in which the atmosphere is transparent are called atmospheric windows. In other words, certain spectral regions of the electromagnetic radiation pass through the atmosphere without much attenuation are called atmospheric windows. The atmosphere is practically transparent in the visible region of the electromagnetic spectrum and therefore, many of the satellite based remote sensing sensors are designed to collect data in this region. Some of the commonly used atmospheric windows are shown in the figure.

Figure . They are: 0.38-0.72 microns (visible), 0.72-3.00 microns (near infra-red and middle infra-red), and 8.00-14.00 microns (thermal infra-red).

Transmission100%UVVisibleInfraredEnergy Blocked0.3 Wavelength (microns)1101001 mm



1.10 SPECTRAL SIGNATURE CONCEPTS-TYPICAL SPECTRAL REFLECTANCE CHARACTRISTICS OF WATER, VEGETATION AND SOIL:

A basic assumption made in remote sensing is that a specific target has anindividual and characteristic manner of interacting with incident radiation. The manner of interaction is described by the spectral response of the target. The spectral reflectance curves describe the spectral response of a target in a particular wavelength region of electromagnetic spectrum, which, in turn depends upon certain factors, namely, orientation of the sun (solar azimuth), the height of the Sun in the sky (solar elevation angle), the direction in which the sensor is pointing relative to nadir (the look angle) and nature of the target, that is, state of health of vegetation.

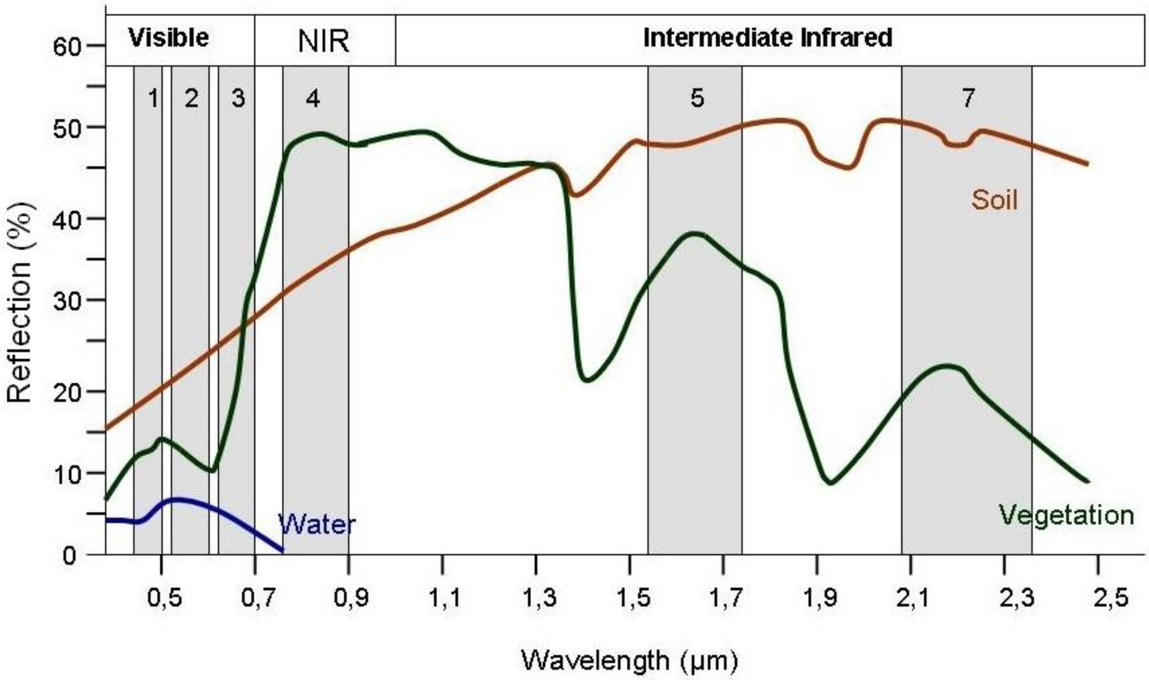


Fig 1.8 Spectral reflectance Curve

Every object on the surface of the earth has its unique spectral reflectance.Fig. 1.8 shows the average spectral reflectance curves for three typical earth's features: vegetation, soil and water. The spectral reflectance curves for vigorous vegetation manifests the "Peak-and-valley" configuration. The valleys in the visible portion of the spectrum are indicative of pigments in plant leaves. Dips in reflectance (Fig. 1.8) that can be seen at wavelengths of 0.65 .µm, 1.4 µm and 1.9 µm are attributable to absorption of water by leaves. The soil curve shows a more regular variation of reflectance. Factors that evidently affect soil reflectance are moisture content, soil texture, surface roughness, and presence of organic matter. The term spectral signature can also be used for spectral reflectance curves. Spectral signature is a set of characteristics by which a material or an object may be identified on any satellite image or photograph within the given range of wavelengths. Sometime&,spectral signatures are used to denote the spectral response of a target.

The characteristic spectral reflectance curve Fig1.8 for water shows thatfrom about 0.5µm, a reduction in reflectance with increasing wavelength, so that in the near infrared range, the reflectance of deep, clear water is virtually a zero (Mather, 1987). However, the spectral reflectance of water is significantly affected by the presence of dissolved and suspended organic and inorganic material and by thedepth of the water body. Fig. 1.8 shows the spectral reflectance curves for visible and near-infrared wavelengths at the surface and at 20 m depth. Suspended solids
in water scatter the down welling radiation, the degree of scatter being proportional to the concentration and the color of the sediment. Experimental studies in the field and in the laboratory as well as experience with multispectral remote sensing have shown that the specific targets are characterized by an individual spectral response. Indeed the successful development of remote sensing of environment over the past decade bears witness to its validity. In the remaining part of this section, typical and representative spectral reflectance curves for characteristic types of the surface materials are considered. Imagine a beach on a

beautiful tropical island. of electromagnetic radiation with the top layer of sand grains on the beach. When an incident ray of electromagnetic radiation strikes an air/grain interface, part of the ray is reflected and part of it is transmitted into the sand grain. The solid lines in the figure represent the incident rays, and dashed lines 1, 2, and 3 represent rays reflected from the surface but have never penetrated a sand grain. The latter are called specular rays by Vincent and Hunt (1968), and surface-scattered rays by Salisbury and Wald
(1992); these rays result from first-surface reflection from all grains encountered. For a given reflecting surface, all specular rays reflected in the same direction, such that the angle of reflection (the angle between the reflected rays and the normal, or perpendicular to the reflecting surface) equals the angle of incidence (the angle between the incident rays and the surface normal). The measure of how much electromagnetic radiation is reflected off a surface is called its reflectance, which is a number between 0 and 1.0. A measure of 1.0 means the 100% of the incident radiation is reflected off the surface, and a measure of 0 means that 0% is reflected.

CHAPTER 2

PLATFORMS AND SENSORS

2.1 TYPES OF PLATFORMS

Thebase,onwhichremotesensorsareplacedtoacquireinformationabouttheEarth's surface,is calledplatform.Platformscanbe stationarylike atripod(forfieldobservation)andstationary balloonsormobilelikeaircraftsandspacecraft's. Thetypesofplatformsdependupontheneeds aswellasconstraintsoftheobservationmission.

Therearethreemaintypesofplatforms, namely 1) Ground borne, 2) Air borne and 3) Space borne.

2.1.1.

GROUNDBORNEPLATFORMS:TheseplatformsareusedonthesurfaceoftheEarth.Cherryarm configuration of Remote Sensing van and tripod are the two commonly used ground borne platforms. Theyhavethecapabilityofviewingtheobjectfromdifferentanglesandare mainly used for collecting the ground truth or for laboratory simulation studies.

2.1.2.

AIRBORNEPLATFORMS: TheseplatformsareplacedwithintheatmosphereoftheEarthandcan be further classified intoballoonsandaircrafts.

a. *Balloons*: Balloons as platforms are not very expensive like aircrafts. They have a great variety of shapes, sizes and performance capabilities. Theballoons have low acceleration,requirenopowerandexhibitlowvibrations. Therearethreemaintypes ofballoonsystems,viz.freeballoons,TetheredballoonsandPoweredBalloons. *Free balloons*can reach almostthetopoftheatmosphere;hencetheycanprovideaplatform at intermediate altitude between those of aircraft and space craft.

Thousands of kilograms of scientific payloads can be lifted by free balloons. Unless a mobile launching system is developed, the flights can be carried out only from a fixed launching station. The free balloons are dependent on meteorological conditions, particularlywinds.Theflight trajectorycannotbecontrolled. Allthesemakeextremely difficulttopredictwhethertheballoonswillflyoverthespecificareaofinterestornot.

InIndia,atpresent,Tata Institute of Fundamental Research,Mumbai,hassetupa NationalballoonfacilityatHyderabad. *Teetheredballoons*areconnectedtotheearth stationbymeansofwireshavinghightensionalstrengthandhighflexibility. The teetheredlinecancarrytheantenna,powerlinesandgastubesetc.whenwindvelocity islessthan35km.perhouratthealtitudeof3000m.,spheretypeballoonisused. When the wind velocity is less than 30 km per hour, natural shape balloons are restrictedtobeplaced. Tetheredballoons havethecapabilityofkeepingtheequipment at a fixed position for a long time and thus, useful for many remote sensing programmers.*Powered balloons*requiresomemeansofpropulsiontomaintainor achieve station overadesignated geographic location. These can be remotely controlledandguidedalongwithapathorfly above a given area within certain limitations.

b. *Aircrafts*: Aircrafts are commonly used as remote-sensing for obtaining Aerial Photographs. In India, four types of aircrafts are being used for remote sensing operations.These are asfollows:

DAKOTA:Theceilingheightis 5.6 to 6.2 kmand minimum speed is 240 km./hr.

AVRO: Ceiling height is 7.5 kmand minimum speed is 600 km./hr.
CESSNA: Ceiling height is 9 km. and minimum speed is 350 km./hr.
CANBERRA: Ceiling height is 40 km.and minimumspeed is 560 km./hr.

The following special aircrafts are being used in abroad for remote sensing operations in high altitude photography.

U-2:Ceilingheightis21km.(forstrategicphotographic).Minimum speedis798 km./hr.

ROCKELL X-15 (Research Craft): Ceiling height is 108 km. and speed is 6620 km./hr.

Theadvantagesofusingaircraftsasremotesensingplatform are:highresolution ofdatarecorded,possibilityofcarryinglargepayloads,capabilityofimaginglarge areaeconomically,accessibility ofremoteareas,convenienceofselectingdifferent scales,adequatecontrolatalltimeetc. However,duetolimitationsofoperating altitudes and range, the aircraftfindsitsgreatestapplicationsinlocalorregional programmeratherthanmeasurementsonglobal scale. Besidesallthese,aircraftshave beenplayinganimportantroleinthedevelopmentofspaceborneremotesensing

Techniques. Testingofsensorsandvarioussystemsandsubsystemsinvolvedinspace borne remote sensing programmeis alwaysundertaken in a well-equipped aircraft.

2.1.3.SPACEBORNEPLATFORMS:Platformsinspace,i.e.satellitesarenotaffectedbytheearth's atmosphere. Theseplatformsmovefreelyintheirorbitsaroundtheearth. Theentireearthor anypartoftheearthcan becovered at specified intervals. Thecoveragemainlydependson theorbitofthesatellite. Itisthroughthesespaceborneplatforms,wegetenormousamount ofremotesensingdataandasaresultRemote Sensinghasgainedinternationalpopularity. Accordingtotheorbitalmode, therearetwotypesof satellites– Geostationary orEarth synchronous and sun-synchronous.

2.2 ORBIT TYPES GEO- SYNCHRONOUS AND SUN-SYNCHRONOUS

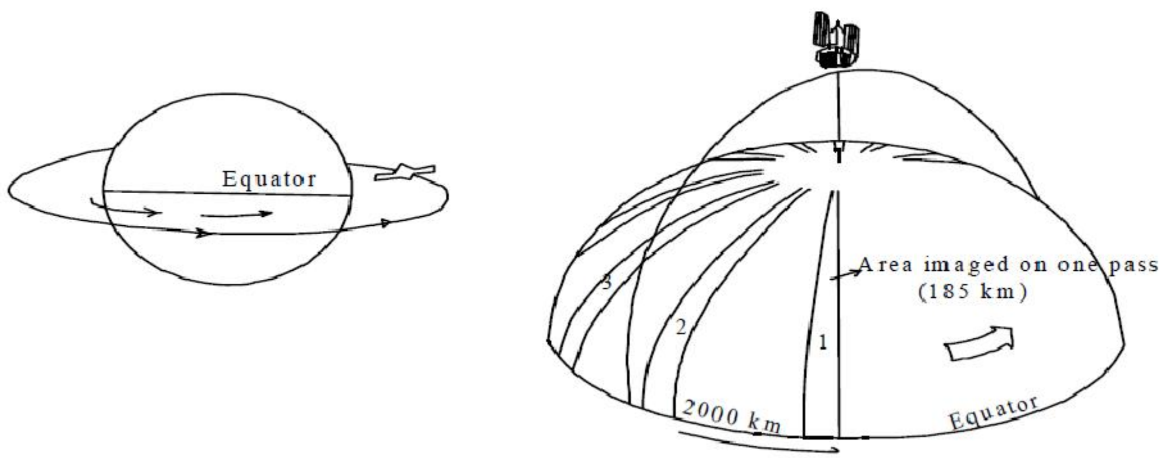


Fig 2.1 Geo – Stationary and Sun synchronous satellites

2.2.1 GEO-

STATIONARYSATELLITES:Geostationarysatellitesarethesatelliteswhichrevolveround theearthabovetheequatorattheheight ofabout36,000to41,000km., inthedirection of earth's rotation. Theymakeonerevolutionin24hours, synchronous withtheearth's rotation(Fig.2).Asaresult,itappearsstationary withrespect toearth. Theseplatforms always cover a specific area and give continuous coverage over the same area day and night. Their coverage is limited to 70 N and 70 S latitudes and one satellite can view onethirdglobe. Thesearemainlyusedforcommunicationandweathermonitoring. Some ofthese satellites are INSAT, METSAT and ERS series.

2.2.2 SUN-SYNCHRONOUSSATELLITES: Sun-synchronoussatellitesarethesatelliteswhichrevolved roundtheearthinnorth-southdirection(poleto pole)attheheightofabout300to1000 km. (Fig.2.1)they pass over places on earth having the same latitude twice in each orbit atthesamelocalsun-time,hencearecalled sun-synchronous satellites. Throughthese satellites, the entire globe is covered on regular basis and gives repetitive coverage on periodicbasis. Alltheremotesensingresourcessatellitesmaybegroupedinthis category. Fewofthesesatellitesare:LANDSAT,IRS,SPOTseriesandNOAA, SKYLAB, SPACE SHUTTLE etc.

2.3 PASSIVE AND ACTIVE SENSORS

Remotesensorsaretheinstrumentswhichdetectvariousobjectsontheearth'ssurface bymeasuringelectromagneticenergyreflectedoremittedfromthem. Thesensorsaremounted ontheplatformsdiscussedabove. Differentsensorsrecorddifferentwavelengthsbandsof electromagneticenergycomingfromtheearth'ssurface. Asforexample,anordinarycamerais the most familiar type ofremote sensor which uses visible portion of electromagnetic radiation.

Classification of Sensors

Remote sensors can be classifiedin different ways as follows.

1. *OntheBasisofSourceofEnergyUsed*:Onthebasisofsourceofenergyusedbythe sensors, they can be classified into two types – Active sensors and Passive sensors.

2.3.1ACTIVESENSORS: Active sensors use their own source of energy and earth surface is illuminatedbythisenergy. Thenapartofthisenergyisreflectedback whichis received by the sensor to gather information about the earth's surface (Fig.3). Whenphotographiccamerausesitsflash,it actsasanactivesensor. Radarand laseraltimeterareactivesensors. Radariscomposedofatransmitteranda receiver. Thetransmitter emitsawave,whichstrikesobjectsandisthenreflected or echoed back to the receiver. The properties of an active sensor are: 1) It uses both transmitter and receiverunitstoproduceimagery, hence it requires high energy levels. 2) It mostly works in microwave regions of EMR spectrum, which can penetrate clouds and is not affected by rain. 3) It is an all weather, day-night system andindependentofsolarradiation.4)TheRADARsignaldoesnotdetect colour information or temperature information, but it can detect the roughness, slope and electrical conductivityof the objects under study.

2.3.2. PASSIVESENSORS:Passivesensorsdonothavetheirownsourceofenergy. The earth surface is illuminated by sun/solar energy. The reflected solar energy from theearthsurfaceortheemittedelectromagneticenergybytheearthsurfaceitself is received by the sensor (Fig.3). Photographic camera is a passive sensor when it isusedinsunlight,withoutusingitsflash.Thepropertiesofapassivesensorare:

1)Itisrelativelysimplebothmechanicallyand electrically anditdoesnothave high power requirement. 2) The wavebands, where natural remittance or reflected levelsarelow,highdetectorsensitivitiesand wideradiation collectionapertures arenecessarytoobtainareasonable signal level. Therefore,mostpassivesensors are relatively wide band systems. 3) It depends upon good weather conditions.

2. *OntheBasisofFunctionofSensors:*Onthebasisoffunctionofsensors,theyaredivided into two main types - Framing System and Scanning System.

   a. *Framingsystem:*Inframingsystem,twodimensionalimagesareformedatone singleinstant. Here,alensisusedtogatherthelightwhichispassedthrough various filters and then focused on a flat photosensitive target. In ordinary camera,thetargetisfilm emulsion,whereasinvidiconcamera,thetargetis electrically charged plate.

   b. *ScanningSystem:*Inscanningsystem,asingledetector/anumberofdetectors withspecificfieldof view,isusedwhichsweepsacross a scene in a series of parallellinesandcollectdataforcontinuouscellstoproduceanimage. Multi SpectralScanner,MicrowaveRadiometer,MicrowaveRadar,OpticalScanners are few examples of scanning system sensors.

3. *OntheBasisofTechnicalComponentsoftheSystem*:Thesensorscanbeclassifiedinto threecategoriesonthebasisoftechnicalcomponentsofthesystem andthecapabilityof thedetection. Theseare:1)Multispectralimagingsensorsystems,2)Thermalremote sensing systems, and 3) Microwave radar sensing systems. The multispectral or multiband imaging systems may use conventional type camers or may use a combination ofbothcamerasandscannersforvarious bandsofelectromagneticenergy.Asfor example,ReturnBeamVidicon(RBV)sensorofLandsatusesbothphotographicandScanning systems,whichissimilartoanordinaryTVcamera. Thethermalsystem uses radiometers,photometers,spectrometers,thermometerstodetectthe temperature changes wheremicrowavesensingsystemsusetheantennaarraysforcollectinganddetectingthe energy from the terrain elements.

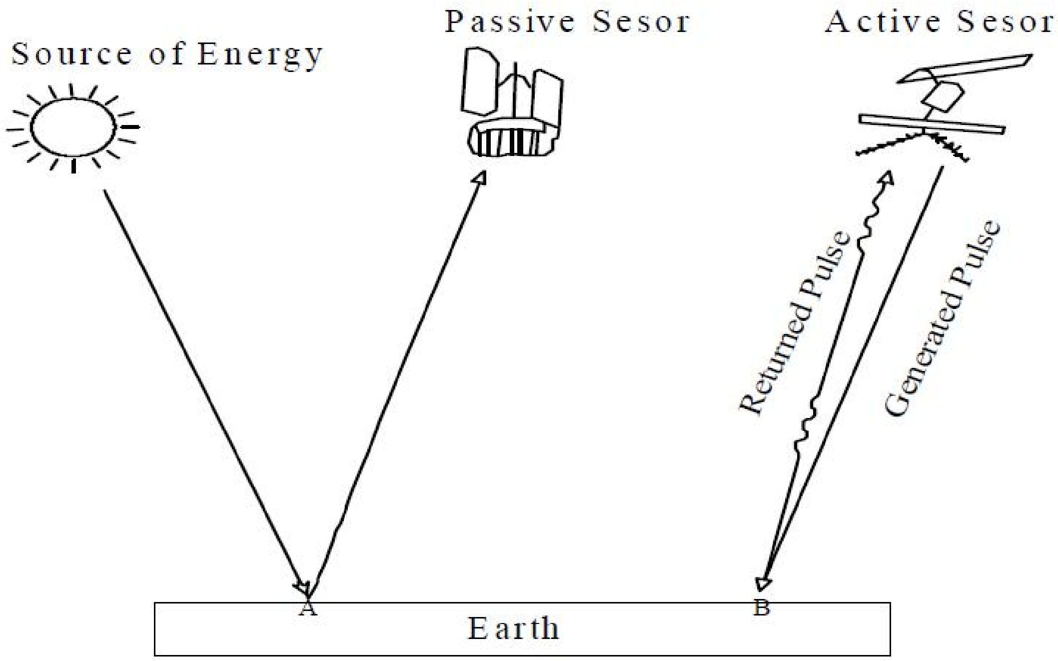


Fig 2.2 active and passive sensor

1.4 RESOLUTION CONCEPT:

1.4.1 SPATIAL RESOLUTION:

It is a measure of the smallest angular or linear separation between two objects that can be resolved by the sensor. The greater the sensor's resolution, the greater the data volume and smaller the area covered. In fact, the area coverage and resolution areinter-dependent and these factors determine the scale of the imagery.

Spatial resolution is a complex concept which can, for the purpose of remotesensing of polar regions, be defined as the smallest object that can be detected and distinguished from a point. The most frequently used measure, based upon the geometriC properties of an imaging system, is the instantaneous field of view (IFOV) of a sensor. The IFOV is the area on the surface that is theoretically viewed by the Instrument from a given altitude at a given time. The spatial resolution is usually determined by instrumental parameters and by the height of the satellite above the ground. With the exception of active microwave systems, the resolution of a system cannot be better than approximately HIID (the diffraction limit), where H is the height, I is the wavelength and 0 is the diameter of the objective lens, objective mirror or antenna. This limit is typically of the order of 10 to 100 m for VIS and IR systems operating from satellites in low orbits, and typically 1 to 10 km when the satellite is geostationary. For passive microwave observations, the resolution limit is much coarser (of the order of tens of km) because of the larger wavelength measured.

It was stated that the best achievable spatial resolution is of the order of HI/D (except for some types of radar system), although some non-radar systems may not reach this resolution because of other instrumental effects. Two important examples are sensors in which the incoming radiation is focused on to an image array of discrete detecting elements, and photographic systems. The detecting element or film imposes its own maximum resolution, again proportional to the height H and, if this is poorer than the diffraction-limited resolution, it will dominate.

The spatial resolution achievable by radar systems is very dependent on theway the data from the system are processed. Such systems are often pulsed, and one important factor is the length of the emitted pulse. Synthetic aperture radars (SARs) also integrate the return signal for a period of time while the radar is carried forward on its platform, and the integration time also influences the resolution. It is not possible to give here a statement of the general principles determining radar spatial resolution, and the interested reader is referred to treatments given by Ulaby, Moore and Fung (1981 and 1982), Elachi (1987) and Rees (1990). Spatial resolution of an imaging system can be measured in a number of different ways. It is the size of the smallest object that can be discriminated by the sensor. The greater the sensor's resolution, the greater the data volume and smaller the area covered. In fact, area coverage and resolution are interdependent and these two factors determine the scale of an imagery. Altematively, spatial resolution can be said to be the length of the size of the area on the ground represented by a pixel on an image. The basIs for the definition of spatial resolution can depend on four criteria, namely, : (i) Geometrical properties of the imaging system, (ii) the ability to distinguish between point targets, (iii) the ability to meaSllre the periodicity of repetitive targets, and (iv) the ability to measure the spectral properties of small targets (Mather, 1999).

Spatial resolution of any satellite sensor applies to the image produced by thesystem, whereas resolving power of any photograph applies to an imaging system or a component of the system. As mentioned earlier, the most commonly used measure for spatial resolution of any sensor, based on the geometric properties of the imaging system, is the Instantaneous Field of View (IFOV) of a sensor. IFOV is defined as thearea on the ground that is viewed by an instrument from a given altitude at any given instant of time. Fig. 2.3 illustrates the relationship between the swath width and the IFOV. The IFOV can be measured in one of the two ways, (i) by measuring angle *"a"*and (ii) by measuring the distance XY on the ground.

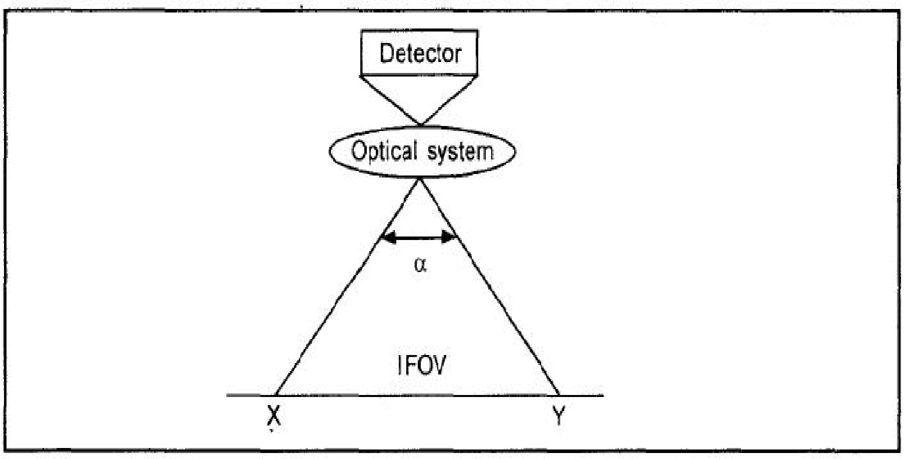


Fig 2.3 IFOV

1.4.2 SPECTRAL RESOLUTION:

It refers to the dimension and number of specific wavelength intervals in the electromagnetic spectrum to which a sensor is sensitive. Narrow bandwidths in certain regions of the electromagnetic spectrum allow the discrimination of various features more easily. Temporal resolution: It refers to how often a given sensor obtains imagery of a particular area. Ideally, the sensor obtains data repetitively to capture unique discriminating characteristics of the phenomena of interest.

It is the width of the spectral band and the number of spectral bands in whichthe image is taken. Narrow band widths in certain regions of the electromagnetic spectrum allow us to discriminate between the various features more easily. Consequently, we need to have more number of spectra! bands, each having a narrow bandwidth, and these bands should together cover the entire spectral range of interest. The digital images collected by satellite sensors except microwave sensing systems like Seasat, SIR B Radarsat, have been multi-band or multispectral, individual images separately recorded in discrete spectral bands. Multispectral imaging refers to viewing a given area in several narrow bands to obtain better identification andclassification of objects. Multistage imaging refers to the observations of the same area from different positions of the platforms (stereoscopic data). Multistage imaging refers to the observations made over the same area on different dates to monitor the objects like crop growth. This is also called temporal resolution. The term spectral resolution refers to the width of the spectral bands. Spectral resolution can be explained by considering two points, (i) the position of the spectrum, width and number of spectral bands will determine the degree to which individual targets can be determined on the multispectral image, and (ii) the use of multispectral imagery can lead to a higher degree of discriminating power than any single band taken on its own.

1.4.3 RADIOMETRIC RESOLUTION:

It is the capability to differentiate the spectral reflectance/ remittance from various targets. This depends on the number of quantization levels within the spectral band. In other words, the number of bits of digital data in the spectral band will decide the Sensitivity of the sensor.

It is the smallest difference in exposure that can be detected in a given film analysis. It is also the ability of a given sensing system to discriminate between density leve:s. In general, the radiometric resolution is inversely proportional to contrast, so that higher contrast film is able to resolve smaller differences in exposure. Low contrast films have greater radiometric range while highest contrast films have smaller exposure range and lower radiometric range.

1.5 PAY LOAD DESCRIPTION OF IMPORTANT EARTH RESOURCES AND METEROLOGICAL SATELLITES

1.5.1 EARTH RESOURCES SATELLITES

There are three distinct groups of earth resources satellites. The first group of satellites record visible and near visible wavelengths. The five satellites of Landsat series which are the first generation earth resources satellites are a classic example of this group. The four IRS satellites and the more improved SPOT series of these satellites may be considered the second generation earth resources satellites of the same group. Group two satellites carry sensors that record thermal infrared wavelengths and include the Heat Capacity Mapping Mission sate·llites, namely, Explorer series. Group three satellites are deployed with sensors that record microwavelengths. The seasat series and the ERS are examples of this group.

1.5.2 LANDSAT SATELLITE PROGRAMME

National Aeronautics and Space Administration (NASA) of USA with the cooperation of the U.S. Department of Interior planned the launching of a series of Earth Resources Technology Satellites (ERTS). ERTS-1 was launched by a ThorDelta rocket on July 23, 1972 and it operated until January 6,1978. It represented the first unmanned satellite designed to acquire data about the earth resources on a systematic, repetitive, medium resolution, multispectral basis. Subsequently, NASA renamed the ERTS programme as "Landsat" programme to distinguish it from the series of meteorological and oceanographic satellites that the USA launched later. ERTS-1 was retrospectively named Landsat-1. Five Landsat satellites have been launched so far and this experimental programme has evolved into an operational global resource monitoring programme. Three different types of sensors have been flown in various combinations on the five missions. These are Return Beam Vidicon (RBV) camera system, the Multispectral Scanner (MSS) system and the Thematic Mapper (TM).

Characteristics of Landsat Satellites and Their Sensors:

Satellite Capabilities :

Particulars	Landsat - 1 to 3	Landsat - 4 & 5
Altitude	919 Km	705 Km
Orbit	Near-Polar Sun-Synchronous	Near-Polar Sun-Synchronous
Inclination	99.09 Degree	98.2 Degrees
Period	103 minutes	99 minutes
Equatorial crossing time	0930 Hours	0945 Hours
Repeat Cycle	18 Days	16 Days
Swath Width	185 Km	185 Km
Data rate	15.06 Mbps	84.9 Mbps

Sensor Capabilities :

Sensor	Mission	Channel	Spectral Spatial Resolution (Microns)	Spatial Resolution	Radiometric Resolution
RBV	Landsat 1 to 3	1	0.475-0.575	80 m	6 bits (127 levels)
		2	0.580-0.680	80 m	
		3	0.690-0.830	80 m	
		4	0.505-0.750	80 m	
MSS	Landsat 1 to 5	1	0.5-0.6	79/82 m*	6 bits (127 levels)
		2	0.6-0.7	79/82 m*	
		3	0.7-0.8	79/82 m*	
		4	0.8-1.1	79/82 m*	
		5	10.4-12.6	240 m	
TM	Landsat 4 & 5	1	0.45-0.52	30 m	8 bits (255 levels)
		2	0.52-0.60	30 m	
		3	0.63-0.69	30 m	
		4	0.76-0.90	30 m	
		5	1.55-1.75	30 m	
		6	2.08-2.35	30 m	
		7	10.4-12.5	120 m	

* The Spatial Resolution is 79 m for Landsat-1, 2 & 3. It is 82 m for Landsat 4 & 5.

1.5.3 SPOT SATELLITE PROGRAMME

France, Sweden and Belgium joined together and pooled up their resources todevelop the System Pourl' Observation dela Terre (SPOT), an earth observation satelliteprogramme. The first satellite of the series, SPOT-1 was launched from Kourou LaunchRange in French Guiana on February 21,1986 aboard an Ariance Launch vehicle (AIV).This is the first earth resource satellite system to include a linear array sensor employingthe push broom scanning technique. This enables side-to-side oft-nadir viewingcapabilities and affords a full scene stereoscopic imaging from two different viewingpoints of the same area. The high resolution data obtained from SPOT sensors, namely,Thematic Mapper (TM) and High Resolution Visible (HRV), have been extensively usedfor urban planning, urban growth assessment, transportation planning, besides theconventional applications related to natural resources.

Characteristics of SPOT Satellite and HRV Sensor Satellite

SPOT Satellite		
Orbit	:	Near-polar Sun-synchronous
Altitude	:	832 km
Inclination	:	98.7 Degrees
Equatorial Crossing Time	:	10.30 Hours
Repeat Cycle	.	26 Days
HRV Sensor		
Channel		**Waveband (Microns) Multispectral**
1		0.50-0.59
2		0.61-0.68
3		0.79-0.89
Panchromatic		
1		0.51-0.73
Spatial resolution	.	20-m (Multispectral) (at nadir) 10 m (panchromatic)
Radiometric resolution	:	8 bits (Multispectral) 6 bits (Panchromatic)
Swath Width	:	117 Km (60 km per HRV, 3 Km overlap)
Angular field of view	:	4.13 Degrees.
Off-nadir viewing	:	$\pm$ 27^0 in 45 steps of 0.6^0 (= $\pm$ Km from nadir)

1.5.4 INDIAN REMOTE SENSING SATELLITE (IRS)

The IRS mission envisages the planning and implementation of a satellite basedremote sensing system for evaluating the natural resources. The principal componentsof the mission are: a three axis stabilised polar sunsynchronous satellite withmultispectral sensors, a ground based data reception, recording and processingsystems for the multispectral data, ground systems for the in-orbit satellite controlincluding the tracking network with the associated supporting systems, and hardwareand software elements for the generation of user oriented data products, data analysisand archival. The principal aim of the IRS mission is to use the satellite data inconjunction with supplementary/complementary information from other sources forsurvey and management of natural resources in important areas, such as, agriculture,geology and hydrology in association with the user agencies. IR$ series of satellitesare IRS lA, IRS IB, IRS IC, IRS ID and IRS P4 apart from other satellites which werelaunched by the Government of India. The orbital and sensor characteristics of IRS IAand IB are the same and IRS IC and IRS ID have almost similar characteristics. IRSP4is an oceanographic satellite, and this will be discussed in the next section. IRS hasapplication potential in a wide range of disciplines such as management of agriculturalresources, inventory of forest resources, geological mapping, estimation of waterresources, study of coastal hydrodynamics, and water quality surveying.The sensor payload system consists of two push broom cameras (LiSS-II) of36.25 m resolution and one camera .(LlSS-I) of 72.5 m resolution employing linearCharge Coupled Device (CCD) arrays as detectors. Each camera system images infour spectral bands in the visible and near IR region. The camera system consists of collecting optics, imaging detectors, inflight calibration equipment, and processing

devices. The orbital characteristics of the IRS-1A, 1 B satellites and the sensorcapabilities are given in Table 4.3. As IRS-1 D satellite is the latest satellite of theseries and hence the system overview of IRS - 1 D is provided.

The IRS-1 D is a three-axes body stabilized satellite, similar to IRS-1 C. SinceIRS-1 C and 1 D are similar in orbital characteristics and sensor capabilities, the detailsof IRS-1 D are discussed as it is a very recent satellite. It will have an operational lifeof three years in a near polar sunsynchronous orbit at a mean altitude of 780 Km.The payload consists of three sensors, namely, Panchromatic camera (PAN), linearimaging and self-scanning sensor (LiSS-III) and wide Field sensor (WiFs). The satelliteis equipped with an On-Board Tape Recorder (OBTR) capable of recording limitedamount of specified sensor data. Operation of each of the sensors can be programmed.

The payload operation sequence for the whole day can be loaded daily on to theon-board command memory when the satellite is within the visibility range. The groundsegment consists of a Telemetry Tracking and Command (TTC) segment comprisinga TTC network, and an Image segment comprising data acquisition, data processingand product generation system along with data dissemination centre. The over viewof IRS-1 D mission is to provide optimum satellite operation and a mission controlcentre for mission management, spacecraft operations and scheduling. The threesensors on board IRS-1 D and IRS-1 C are described in the following paragraph.

The panchromatic camera provides data with a spatial resolution of 5.2-5.8 m(at nadir) and a ground swath between 63 Km -70 Km (at nadir). It operates in the0.50 - 0.75 microns spectral band. This camera can be steered upto ± 26 deg.storable upto ±398 Km across the track from nadir, which in turn increases the revisitcapability to 3 days for most part of the cycle and 7 days in some extreme cases.

Characteristics of Satellite		
Orbit	:	Near-polar, Sun-synchronous
Altitude	:	904 Km
Inclination	:	99.03 Degrees
Equatorial Crossing Time	:	10.00 Hours
Repeat Cycle	:	22 days
Eccentricity	:	0.002
Period	:	103 minutes

Sensor Capabilities

Linear Image Scanning System : LISS

No. of LISS Cameras	LRC (One)*	MRC (two)**
No. of Spectral Bands	4	4
IFOV (Microrad)	80	40
Geometric Resolution	72.5	36.25
Swath Width	148 Km	74 Km
Radiometric Resolution	7 bits	7 bits
Band-to-Band	0.5	0.5

* Low Resolution Camera
** Medium Resolution Camera

2.6 METEROLOGICAL SATELLITES:

Meteorological satellites designed specifically to assist. in weather predictionand monitoring, generally incorporate sensors that have very coarse spatial resolution compared to land-oriented systems. These satellites, however, afford a high frequency global coverage. USA has launched a multiple series of meteorological satellites with a wide range of orbit and sensing system designs. The first of these series is called the NOAA, an acronym for National Oceanic and Atmospheric Administration. These satetlites are in near-polar, sunsynchronous orbits similar to those of 'Landsat and IRS'. In contrast, another series of satellites which are of essentially meteorological type, called Geostationary Operational Environmental Satellite (GOES) series and Meteosat operated by European Space Agency, are geostationary, remaining in a constant relative position over the equator.

2.6.1 NOAA SATELLITES

Several generations of satellites in the NOAA series have been placed in orbit.The satellites NOAA-6 through NOAA-10 contained Advanced Very High Resolution

Radiometer (AVHRR). The even-numbered missions have daylight (7.30 A.M.) north-to-south equatorial crossing and the odd-numbered missions have night time (2.30 A.M.) north-to-south equatorial crossing. The basic characteristics of these missions and the AVHRR instrument are listed in Table 4.8. Apart from routine climatological analyses, the AVHRR data have been used extensively in studies of vegetation dynamics, flood monitoring, regional soil moisture analysis, dust and sandstorm monitoring, forest wild fire mapping, sea surface temperature mapping, and various geological applications, including observation of volcanic eruptions, and mapping of regional drainage and physiographic features.

2.6.1.1 Details of NOAA Satellite and AVHRR Sensor
Characteristics of Satellite

NOAA Satellite		
Orbit	:	Near-polar, Sun-synchronous
Altitude	:	833-870 Km
Inclination	:	98.7 Degrees
Equatorial crossingTime	:	0730 and 1930 Hours
		1400 and 0200 Hours
Repeat Cycle	:	12 Hours
Period	:	102 Minutes

AVHRR Sensor Capabilities		
Channel		**Waveband (Microns)**
1		0.58 - 0.68
2		0.725 - 1.10
3		3.55 - 3.93
4		10.3 - 11.3
5		11.5 - 12.5
Spatial resolution	:	1.1 Km (at nadir)
Radiometric resolution	:	10 bits (1024 levels)
Swath Width	:	3000 Km.

2.6.2 GOES SATELLITES

The GOES programme is a cooperative venture between NOM and NASA. The Geo-stationary Operational Environmental Satellites (GOES) are part of a global network of meteorological satellites spaced about 70° longitude apart around the world. The GOES images are distributed in near real-time for use in local weatherforecasting. They have also been used in certain large area analyses such as regional snow cover mapping.

GOES Satellite		
Orbit	:	Geostationary
Altitude	:	33,367-48,390 Km
Inclination	:	1.9 - 0.2 Degrees
Repeat Cycle	:	Twice per hour
Period	:	1430 - 1436 Minutes
Visible Infrared Spin Scan Radiometer (VISSR)		
Channel	**Waveband (Microns)**	**Ground Resolution**
1	0.55-0.70	14 Km
2	10.5-12.6	8 Km
VISSR Atmospheric Sounder (VAS)		
1	0.55-0.70	14 Km
2	4.496-14.81	16 Km

2.6.3 NIMBUS SATELLITES

This is one of the ocean monitoring satellites launched in October 1978. This satellite carries the Coastal Zone Colour Scanner (CZCS) designed specifically to measure ocean parameters. The details of the six bands in which the CZCS operates and the characteristics of NIMBUS-7 satellite are presented in Table 4.10 The CZCS has been used to measure sea surface temperatures, detection of chlorophyll and suspended solids of near-shore and coastal waters.

2.7 AIR BORNE AND SPACEBORNE TIR AND MICROWAVE SENSORS

Components of sensor systems operating in the visible, infrared, thermaland microwave regions of the electromagnetic spectrum are described in this section.Although analogue photographic imagery has many advantages, this book is mainly concerned with image data collected by scanning systems that ultimately generate digital image products. It is apparent that the useful wavebands are mostly in the visible and the infrared for passive remote sensing detectors and in the radar and microwave region for active type of sensors. Accordingly the imaging sensor systemsin remote sensing are classified as shown in Fig.2.4

In the case of multiband photographic system, different parts of the spectrumare sensed with different film-filter combinations. Multiband digital camera images and video images are also typically exposed on to the camera's CCD or CMOS sensor (s) through different filters. Electro-optical sensors, such as, the thematic mapper of Landsat, typically sense in atleast several bands of electromagnetic spectrum.

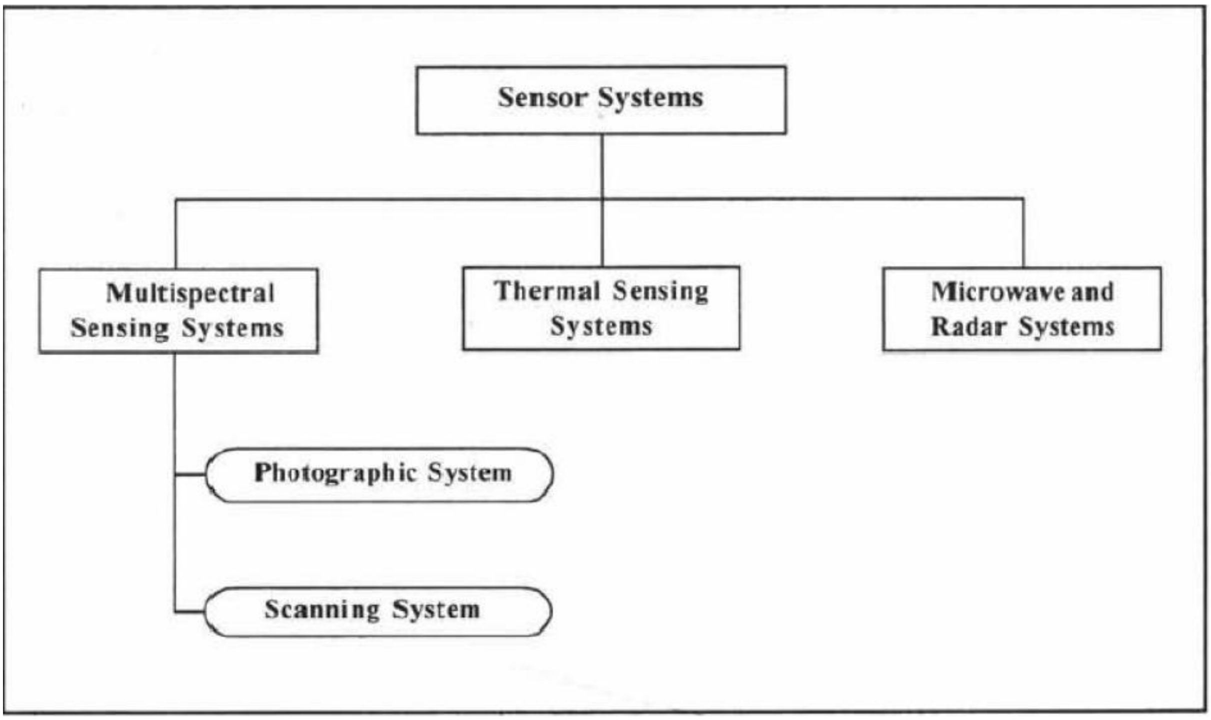


Fig 2.4 Sensor System

The photographic system suffers from one major defect of considerable distortion at the edges. This is due to a large lens opening. From lens theory, we know that distortions can be minimised and resolution considerably improved by using a narrow beam of light. This can be achieved by a system called scanning system. A multispectral scanner (MSS) operates on the same principle of selective sensing in multiple spectral bands, but such instruments can sense in many more bands and over a great range of the electromagnetic spectrum. Because of the advancement in utilising electronic detectors, MSS can extend the range of sensing
from 0.3 flm to 14 flm. Further MSS can sense in very narrow bands. Multispectral scanner images are acquired by means of two basic process: across-track and along-track scanning. Multispectral scanner systems build up two-dimensional images of the terrain for a swath beneath the platform. Across-track systems are also called whisk broom scanner systems. This type of scanning system scans the terrain along scanlines that are right angles to the direction of the spaceborne/airborne platform. Fig. 4.8 illustrates the operation across-track system.

In this type of scanning system, scanner repeatedly measures the energy from one side of the aircraft to the other. Data are collected within an arc below the aircraft typically of 900 to 1200. Successive scan lines are covered as the aircraft moves forward, yielding a series of contiguous or narrow strips of observation comprising a two-dimensional image of rows (scan lines) and columns. At any instant, the scanner'sees' the energy within the systems IFOV. This explains the spatial resolution of the sensing.

The second type of multispectral scanning system is along-track scanning systemor push broom systems. This type of scanners record multiband image data along a swath beneath an aircraft. As the aircraft/spacecraft advances in the forward direction, the scanner scans the earth with respect to the designed swath to build a twodimensional image by recording successive scanlines that are oriented at right angles to the direction of the aircraft/spacecraft.

2.7.1THERMAL SENSING SYSTEMS

Thermal scanner is one of the most important thermal sensing systems, particular kind of across track multispectral scanner which senses in the thermal portion of the electromagnetic spectrum by means of inbuilt detectors. These systems are restricted to operating in either 3 to 5 I-lm or 8 to 14 I-lm range of wavelengths. The operation and the efficiency of this type of scanning systems are based on thecharacteristics of the detectors. Quantum or photon detectors are typically used to detect the thermal radiation. These detectors operate on the principle of direct interaction between photons of radiation incident on them and the energy levels of electrical charge carriers within the detector material.

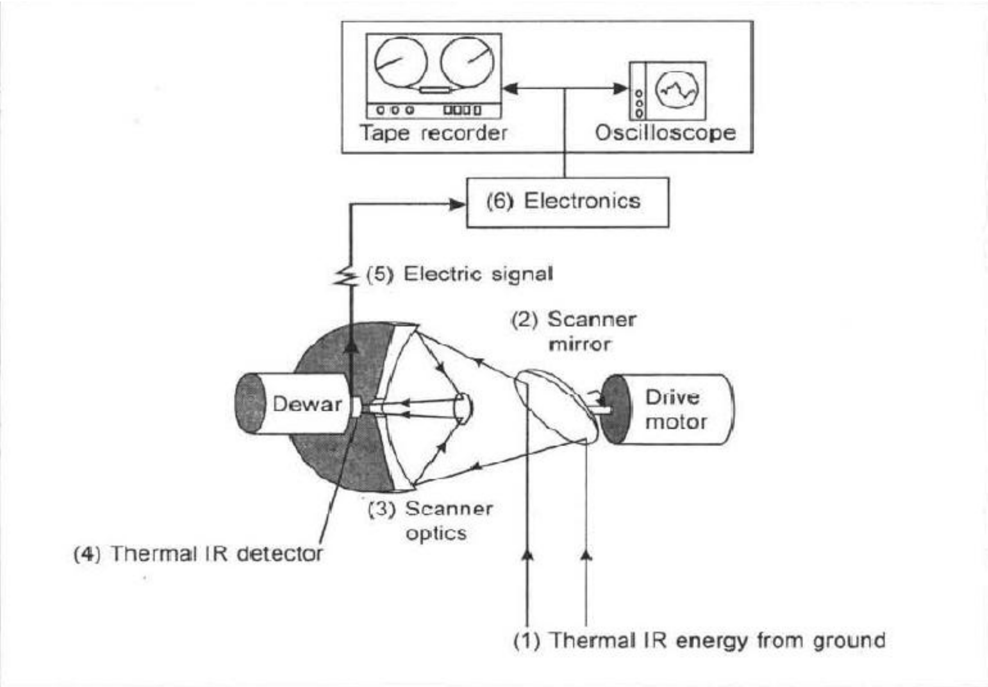


Fig 2.5 thermal Sensing System

2.7.2 MICROWAVE IMAGING SYSTEMS

The fundamental principle of microwave sensing and the conceptual design of radar have been discussed in chapter 3, where it is stated that the microwave region of the electromagnetic spectrum includes radiation with wavelengths longer than 1 mmImaging. Microwave instruments do not, however, rely on the detection of solar or terrestrial emissions. In the following sections of this chapter, the properties of the operational synthetic aperture radar (SAR) systems and Radarsat systems are presented along with other sensing systems.

CHAPTER – 3

IMAGE INTERPRETATION AND ANALYSIS

3.1 TYPES OF DATA PRODUCTS

The main interest of social scientists and applied scientists is the data produced by Remote Sensing technique. The Remote Sensing data are of two types – pictorial and digital. These data products are described in the following paragraphs:

3.1.1 DIGITAL DATA PRODUCTS*:*

The digital data products give information in the form of array of small cells having quantitative values which is the function of the electromagnetic energy radiated from all objects within the field of view. A digital data product is called digital image. A digital image is a two dimensional array of pixels (picture elements). Each pixel represents an area on the earth's surface and has an intensity value (represented by a digital number) and a location address (referenced by its row and column number). The intensity value represents the measured solar radiance in a given wavelength band reflected from the ground. The location address is a one-to-one correspondence between the column-row address of a pixel and the geographical coordinates (e.g. latitude and longitude) of the imaged location. The digital image is a vast matrix of numbers and is very often stored in amagnetic tape and in particular in a computer compatible tapes (CCT). The digital data can be converted into photographic image.

3.1.2 PICTORIAL DATA PRODUCTS

The pictorial data products give information of objects on the earth surface in the form of photographs or images. The pictorial products provided by aircrafts are called aerial photographs. These are generally taken by sophisticated cameras which use visible portion of electromagnetic energy. Therefore, aerial photographs give the exact view / picture of objects on the earth surface on reduced scale. The aerial photographs may be black and white or may be coloured, it depends upon the camera used in aircraft. The pictorial data products provided by satellites are called satellite images. These images are generally taken by sensors which use both visible and invisible portion of electromagnetic energy. The satellite images can be black and white or can be coloured. The black and white pictures or images are produced from each band of digital data. For a particular band, black and white image is generated by assigning different shades of grey (white to black) to its digital data. Likewise unicolour images (blue, green, red etc.) can be generated by assigning different shades of blue / green/ red to a particular band data. When any three bands are combined, it gives multi coloured imagery. If images are taken in blue, green and red bands (visible portion of electromagnetic energy) respectively, they can be combined to give natural colour image. If images are taken in green, red (visible portion of electromagnetic energy) and infrared band (invisible portion of electromagnetic energy) and blue, green and red colours are assigned to them respectively and then they are combined together, it will produce a False Colour Composite (FCC) image. The FCC image does not give the exact picture / view of the earth's surface like aerial photographs. The lay person cannot visualize anything from FCC image. Only an expert can interpret it.

3.2 TYPES OF IMAGE INTERPRETATION

We have studied two major types of Remote Sensing data products, viz. pictorial and digital. The pictorial data products, such as aerial photographs and satellite imageries are interpreted visually. Likewise, digital data products or digital images are interpreted mathematically by using computer software. So, there are two ways of Remote Sensing data interpretation – 1) Visual Interpretation and 2) Digital Interpretation

3.2.1 VISUAL INTERPRETATION:

Both aerial photographs and satellite imageries are interpreted visually. Photogrammetry is the science which study interpretation of aerial photographs. To interpret aerial photographs, a number of sophisticated instruments such as pocket stereoscope, mirror stereoscope, plotter is used in photogrammetry for measuring area, height, slopes of different parts of earth photographed and also for plotting different objects / Themes from aerial photographs. With the development of science and technology, satellite imageries become more and more popular gradually. Satellite image interpretation is an art of examining images for the purpose of identifying objects and judging their significance. Interpreters study remote sensing image logically and attempt to identify, measure and evaluate the significance of natural and cultural features. Image interpretation technique requires extensive training and is labour intensive. Information extraction from imageries is based on the characteristics of image features, such as size, shape, tone, texture, shadow, pattern, association etc. Though this approach is simple and straight forward, it has following short comings: i) The range of gray values product on a film or print is limited in comparison to what can be recorded in digital form, ii) Human eye can recognize limited number of colour tones, so full advantage of radiometric resolution cannot be used, iii) Visual interpretation poses serious limitation when we want to combine data from various sources.

3.2.2 DIGITAL INTERPRETATION

Digital interpretation facilitates quantitative analysis of digital data with the help of computers to extract information about the earth surface. Digital interpretation is popularly known as 'Image Processing'. Image processing deals with image correction, image enhancement and information extraction. *Image correction* means to correct the errors in digital image. Errors are resulted due to two reasons. When errors are resulted due to defect in sensor (as for example if one of the detector out of 'n' number of detectors does not work), it is called radiometric error. When errors are resulted due to earth rotation, space craft velocity, atmosphere attenuation etc., it is called geometric error. Both radiometric and geometric errors / noise in images are reduced through different techniques with the help of computer. *Image Enhancement deals* with manipulation of data for improving its quality for interpretation. Sometimes digital image lacks adequate contrast, as a result different objects cannot be recognized properly. So, the image requires contrast improvement. Through different image enhancement technique,contrast is improved in digital image. After image correction / rectification, and contrast enhancement, information's are extracted from the digital image, which is the ultimate goal of an interpreter. In *Information Extraction*, spectral values of pixels are analyzed through computer to identify / classify objects on the earth surface. In other words, spectrally homogenous pixels in the image are grouped together and differentiated from other groups. In this way, different features of earth are recognised and classified. The field knowledge and other sources of information also help in recognition and classification processes.

3.3 BASIC ELEMENTS OF IMAGE INTERPRETATION

As we noted in the previous section, analysis of remote sensing imagery involves the identification of various targets in an image, and those targets may be environmental or artificial features which consist of points, lines, or areas. Targets may be defined in terms of the way they reflect or emit radiation. This radiation is measured and recorded by a sensor, and ultimately is depicted as an image product such as an air photo or a satellite image.

What makes interpretation of imagery more difficult than the everyday visual interpretation of our surroundings? For one, we lose our sense of depth when viewing a two-dimensional image, unless we can view it **stereoscopically** so as to simulate the third dimension of height. Indeed, interpretation benefits greatly in many applications when images are viewed in stereo, as visualization (and therefore, recognition) of targets is enhanced dramatically.

Viewing objects from directly above also provides a very different perspective than what we are familiar with. Combining an unfamiliar perspective with a very different scale and lack of recognizable detail can make even the most familiar object unrecognizable in an image.

Finally, we are used to seeing only the visible wavelengths, and the imaging of wavelengths outside of this window is more difficult for us to comprehend. Recognizing targets is the key to interpretation and information extraction. Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of **tone, shape, size, pattern, texture, shadow, and association**.

Visual interpretation using these elements is often a part of our daily lives, whether we are conscious of it or not. Examining satellite images on the weather report, or following high speed chases by views from a helicopter are all familiar examples of visual image interpretation. Identifying targets in remotely sensed images based on these visual elements allows us to further interpret and analyze.

Tone refers to the relative brightness or colour of objects in an image. Generally, toneis the fundamental element for distinguishing between different targets or features. Variations in tone also allows the elements of shape, texture, and pattern of objects to be distinguished.

Ground objects of different colour reflect the incident radiation differentlydepending upon the incident wave length, physical and chemical constituents of the objects. The imagery as recorded in remote sensing is in different shades or tones. For example, ploughed and cultivated lands record differently from fallow fields. Tone is expressed qualitatively as light, medium and dark. In SLAR imagery, for example, the shadows cast by non-return of the microwaves appear darker than those parts where greater reflection takes place. These parts appear of lighter tone. Similarly in thermal imagery objects at higher temperature are recorded of lighter tone compared to objects at lower temperature, which appear of medium to darker tone. Similarly top soil appears as of dark tone compared to soil containing quartz sand. The coniferous trees appear in lighter tone compared to broad leave tree clumps.

Size of objects in an image is a function of scale. It is important to assess the size of atarget relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target. A quick approximation of target size can direct interpretation to an appropriate result more quickly. For example, if an interpreter had to distinguish zones of land use, and had identified an area with a number of buildings in it, large buildings such as factories or warehouses would suggest commercial property, whereas small buildings would indicate residential use.

Pattern refers to the spatial arrangement of visibly discernible objects. Typically an Orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees and urban streets with regularly spaced houses are good examples of pattern.

Texture refers to the arrangement and frequency of tonal variation in particular areas of animage. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas smooth textures would have very little tonal variation. Smooth textures are most often the result of uniform, even surfaces, such as fields, asphalt, or grasslands. A targetwith a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance. Texture is one of the most important elements for distinguishingfeatures in radar imagery.

Shadows cast by objects are sometimes important clues to their identification and Interpretation. For example, shadow of a suspension bridge can easily be discriminated from that of cantilever bridge. Similarly circular shadows are indicative of coniferous trees. Tall buildings and chimneys, and towers etc., can easily be identified for their characteristic shadows. Shadows on the other hand can sometimes render interpretation difficult i.e. dark slope shadows covering important detail.

Association takes into account the relationship between other recognizable objects orfeatures in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification. In the example given above, commercial properties may be associated with proximity to major transportation routes, whereas residential areas would be associated withschools, playgrounds, and sports fields. In our example, a lake is associated with boats, a marina, and adjacent recreational land.

3.4 VISUAL INTERPRETATION KEYS

Keys that provide useful reference of refresher materials and valuable trainingaids for novice interpreters are called image interpretation keys. These image interpretation keys are very much useful for the interpretation of complex imageries or photographs. These keys provide a method of organising the information in a consistent manner and provide guidance about the correct identification of features or conditions on the images. Ideally, it consists of two basic parts' (i) a collection of annotated or captioned images (stereopalrs) illustrative of the features or conditions to be identified, and (ii) a graphic or word description that sets forth in some systematic fashion the image recognition characteristics of those features or conditions. There are two types of keys: selective key and elimination key.

Selective Key

Selective key is also called reference key which contains numerous examples images with supporting text. The interpreter select one example image that most nearly resembles the fracture or condition found on the image under study.

Elimination Key

An elimination key is arranged so that interpretation process step by step from general to specific, and leads to the elimination of all features of conditions except the one being identified**.** Eliminationkeys are also called dichotomous keys where the interpreter makes a series of choices between two alternatives and progressively eliminates all but one possible answer.

3.5 DIGITAL IMAGE PROCESSING

3.5.1 Introduction

As seen in the earlier chapters, remote sensing data can be analysed using visual image interpretation techniques if the data are in the hardcopy or pictorial form. It is used extensively to locate specific features and conditions, which are then geocoded for inclusion in GIS. Visual image interpretation techniques have certain disadvantages and may require extensive training and are labour intensive. In this technique, the spectral characteristics are not always fully evaluated because of the limited ability of the eye to discern tonal values and analyse the spectral changes. If the data are in digital mode, the remote sensing data can be analysed using digital image processing techniques and such a database can be used in raster GIS. In applications where spectral patterns are more informative, it is preferable to analyse digital data rather than pictorial data.

In today's world of advanced technology where most remote sensing data are recorded in digital format, virtually all image interpretation and analysis involves some element of digital processing. Digital image processing may involve numerous procedures including formatting and correcting of the data, digital enhancement to facilitate better visual interpretation, or even automated classification of targets and features entirely by computer. In order to process remote sensing imagery digitally, the data must be recorded and available in a digital form suitable for storage on a computer tape or disk. Obviously, the other requirement for digital image processing is a computer system, sometimes referred to as an **image analysis system**, with the appropriate hardware and software to process the data. Several commercially available software systems have been developed specifically for remote sensing image processing and analysis.

For discussion purposes, most of the common image processing functions available in image analysis systems can be categorized into the following four categories:

Preprocessing

Image Enhancement

Image Transformation

Image Classification and Analysis

3.5.2 PREPROCESSING

Preprocessing functions involve those operations that are normally required prior tothe maindata analysis and extraction of information, and are generally grouped **as radiometric orgeometric corrections**. Radiometric corrections include correcting the data for sensorirregularities and unwanted sensor or atmospheric noise, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor. Geometric corrections include correcting for geometric distortions due to sensor-Earth geometryvariations, and conversion of the data to real world coordinates (e.g. latitude and longitude) on the Earth's surface. The objective of the second group of image processing functions grouped under the term of **image enhancement**, is solely to **improve the appearance of theimagery** to assist in visual interpretation and analysis. Examples of enhancement functionsinclude contrast stretching to increase the tonal distinction between various features in a scene, and **spatial filtering** to enhance (or suppress) specific spatial patterns in an image.

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 combined processing of data from multiple spectral bands. Arithmetic operations (i.e. subtraction, addition, multiplication, division) are performed to combine and transform the original bands into "new" images which better display or highlight certain features in the scene. We will look at some of these operations including various methods of **spectral or band** ratioing, and a procedure called **principal components analysis** which is used to more efficiently represent the information

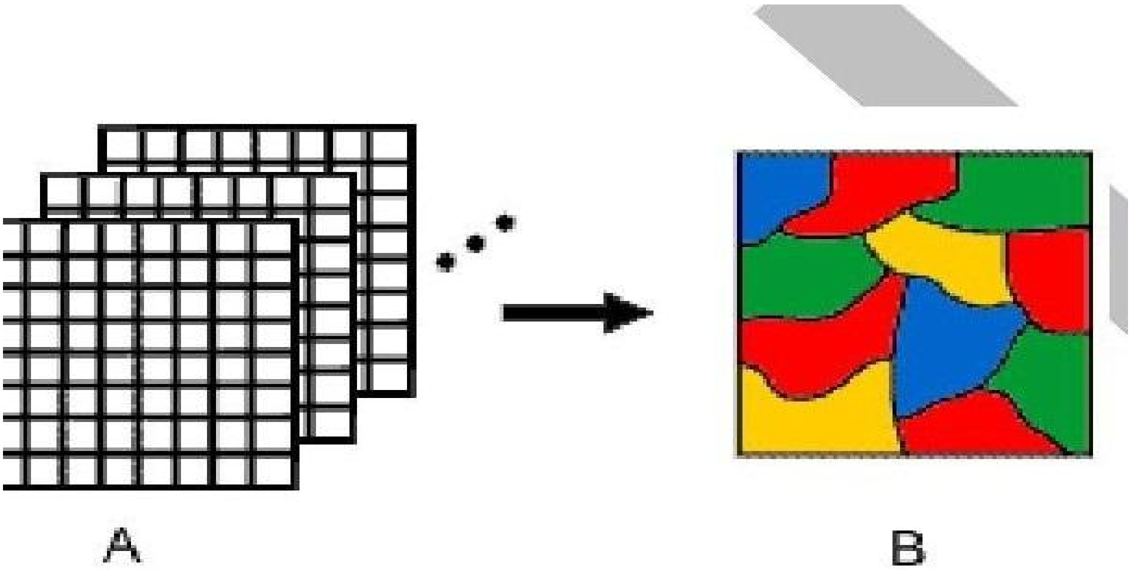


Image classification and analysis operations are used to digitally identify and classify pixelsin the data. **Classification** is usually performed on multi-channel data sets (A) and this process assigns each pixel in an image to a particular class or theme (B) based on statistical characteristics of the pixel brightness values. There are a variety of approaches taken to perform digital classification. We will briefly describe the two generic approaches which are used most often, namely **supervised** and **unsupervised** classification. In the following sections we will describe each of these four categories of digital image processing functions in more detail.

Pre-processing operations, sometimes referred to as image restoration and rectification, are intended to correct for sensor- and platform-specific radiometric and geometric distortions of data. Radiometric corrections may be necessary due to variations in scene illumination and viewing geometry, atmospheric conditions, and sensor noise and response. Each of these will vary depending on the specific sensor and platform used to acquire the data and the conditions during data acquisition. Also, it may be desirable to convert and/or calibrate the data to known (absolute) radiation or reflectance units to facilitate comparison between data.

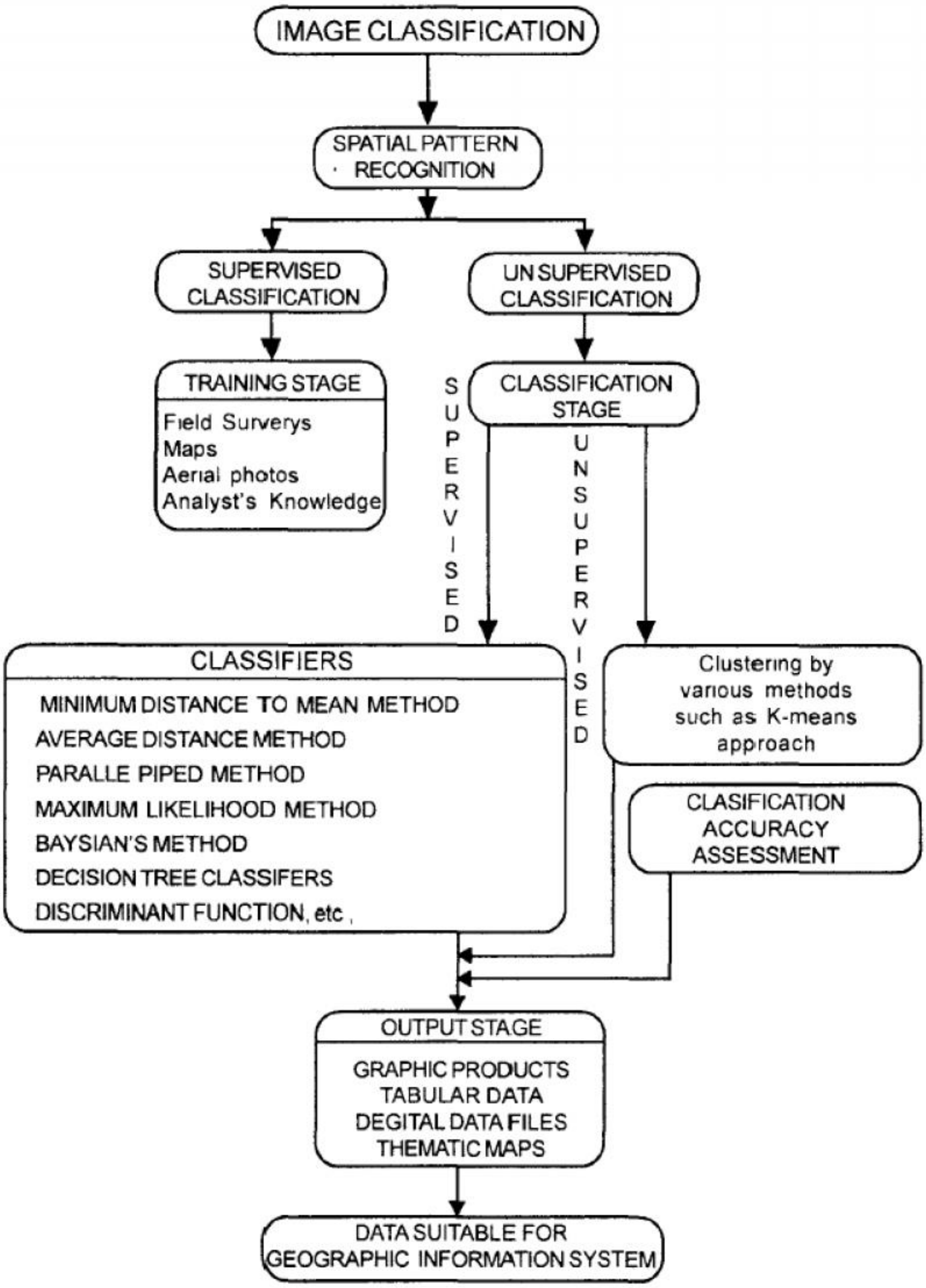
3.5.3 IMAGE ENHANCEMENT TECHNIQUES

Low sensitivity of the detectors, weak signal of the objects present on the earth surface, similar reflectance of different objects and environmental conditions at the time of recording are the major causes of low contrast of the image. Another problem that complicates photographic display of digital image is that the human eye is poor at discriminating the slight radiometric or spectral differences that may characterize the features. The main aim of digital enhancement is to amplify these slight differences for better clarity of the image scene. This means digital enhancement increases the separability (contrast) between the interested classes or features. The digital image enhancement may be defined as some mathematical operations that are to be applied to digital remote sensing input data to improve the visual appearance of an image for better interpretability or subsequent digital analysis (Lillesand and Keifer, 1979). Since the image quality is a subjective measure varying from person to person , there is no simple rule which may produce a single best result. Normally, two or more operations on the input image may suffice to fulfil the desire of the analyst, although the enhanced product may have a fraction of the total information stored in the original image. This will be realized after seeing the different contrast enhancement techniques in this
chapter. There are a number of general categories of enhancement techniques. As in many outer areas of knowledge, the distinction between one type of analysis andanother is a matter of personal taste and need of the interpreter. In remote sensing literature, many digital enhancement algorithms are available.

They are contrast stretching enhancement, ratioing , linear combinations, principalcomponent analysis, and spatial filtering . Broadly, the enhancement techniques are categorised as point operations and local operations. Point operations modify the values of each pixel in an image data set independently, whereas local operations modify the values of each pixel in the context of the pixel values surrounding it. Point operations include contrast enhancement and band combinations, but spatial filtering is an example of local operations. In this section, contrast enhancement, linear contrast stretch , histogram equalisation, logarithmic contrast enhancement, and exponential contrast enhancement are considered.

3.6 IMAGE CLASSIFICATION

Image classification is a procedure to automatically categorize all pixels in an image of a terrain into land cover classes. Normally, multispectral data are used to perform the classification of the spectral pattern present within the data for each pixel is used as the numerical basis for categorization. This concept is dealt under thebroad subject, namely, Pattern Recognition. Spectral pattern recognition refers to the family of classification procedures that utilizes this pixel-by-pixel spectral information as the basis for automated land cover classification. Spatial pattern recognition involves the categorization of image pixels on the basis of the spatial relationship with pixels surrounding them. Image classification techniques aregrouped into two types, namely supervised and unsupervised. The classification process may also include features, such as, land surface elevation and the soil type that are not derived from the image. A pattern is thus a set of measurements on the chosen features for the individual to be classified. The classification process may therefore be considered a form of pattern recognition, that is, the identification of the pattern associated with each pixel position in an image in terms of the characteristics of the objects or on the earth's surface.



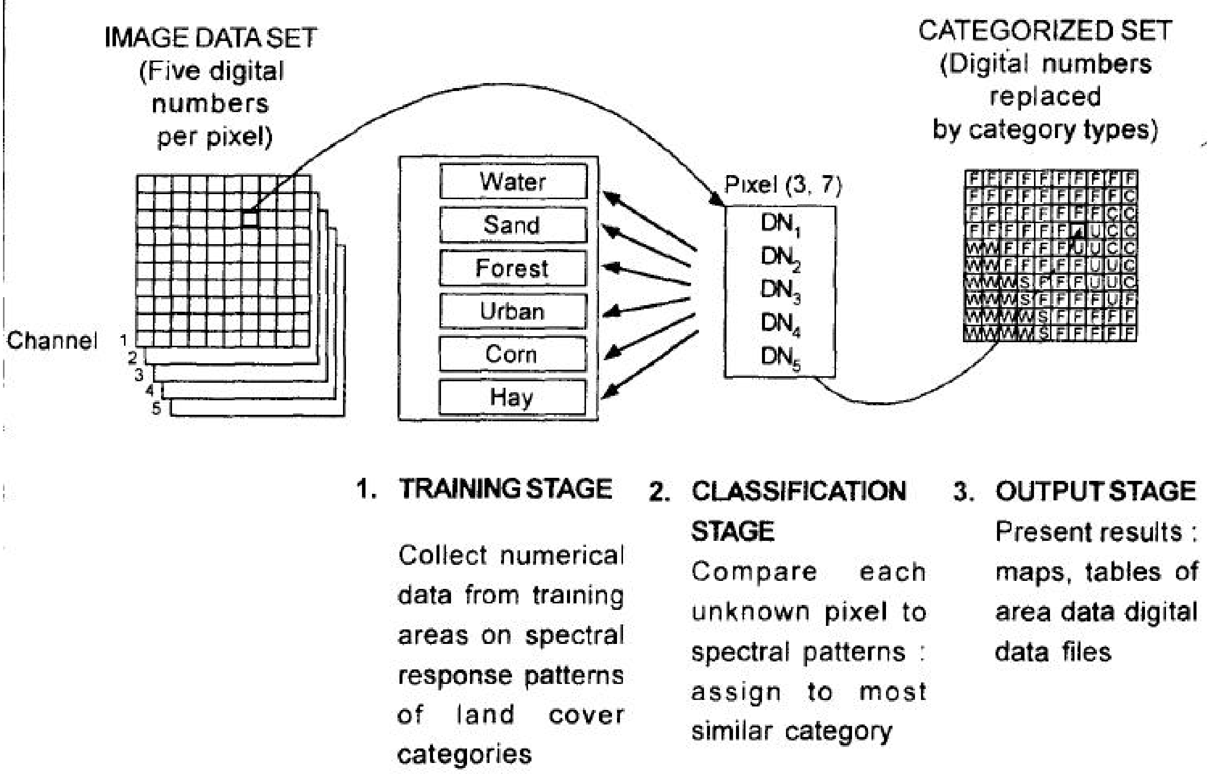
3.6.1 SUPERVISED CLASSIFICATION

A supervised classification algorithm requires a *training sample* for each class, that is, a collection of data points known to have come from the class of interest. Theclassification is thus based on how "close" a point to be classified is to each training sample. We shall not attempt to define the word "close" other than to say that both geometric and statistical distance measures are used in practical pattern recognition algorithms. The training samples are representative of the known classes of interest to the analyst. Classification methods that relay on use of training patterns are called supervised classification methods. The three basic steps (Fig. 6.23) involved in a typical supervised classification procedure are as follows:

(i) *Training stage:* The analyst identifies representative training areas and develops numerical descriptions of the spectral signatures of each land cover type of interest in the scene.

(ii) *The classification stage:* Each pixel in the image data set IS categorised intothe land cover class it most closely resembles. If the pixel is insufficientlysimilar to any training data set it is usually labeled 'Unknown'.

(iii) *The output stage:* The results may be used in a number of different ways.Three typical forms of output products are thematic maps, tables and digitaldata files which become input data for GIS. The output of image classificationbecomes input for GIS for spatial analysis of the terrain.



3.6.2 UNSUPERVISED CLASSIFICATION

Unsupervised classification algorithms do not compare .points to be classified with training data. Rather, unsupervised algorithms examine a large number of unknown data vectors and divide them into classes based on properties inherent to the data themselves. The classes that result stem from differences observed in the data. In particular, use is made of the notion that data vectors within a class should be in some sense mutually close together in the measurement space, whereas data vectors in different classes should be comparatively well separated. If the components of the data vectors represent the responses in different spectral bands, the resulting classes might be referred to as spectral classes, as opposed to information classes, which represent the ground cover types of interest to the analyst. The two types of classes described above, information classes and spectralclasses, may not exactly correspond to each other. For instance, two information classes, corn and soyabeans, may look alike spectrally. We would say that the two classes are not separable spectrally. At certain times of the growing season corn and soyabeans are not spectrally distinct while at other times they are. On the other hand a single information class may be composed of two spectral classes. Differences in planting dates or seed variety might result in the information class" corn" being reflectance differences of tasseled and untasseled corn. To be useful, a class must be of informational value and be separable from other classes in the data.

CHAPTER 4
GEOGRAPHIC INFORMATION SYSTEM

4.1 INTRODUCTION:

The expansion of GIS is Geographic Information System which consists of three words, viz. Geographic,InformationandSystem. Heretheword'Geographic'dealswithspatialobjects or featureswhichcanbereferencedorrelatedtoaspecificlocation ontheearthsurface. Theobject maybephysical/naturalormaybe cultural/manmade. Likewisetheword'Information' deals withthelargevolumeofdataaboutaparticularobjecton theearthsurface. Thedataincludesa setofqualitativeandquantitativeaspectswhichtherealworldobjectsacquire.

Theterm 'System'is used to represent systems approach wherethecomplexenvironment(consistsofa largenumber,ofobjects/featuresontheearthsurfaceandtheircomplexcharacteristics)is brokendownintotheircomponentpartsforeasyunderstandingandhandling,butisconsidered toform anintegratedwholeformanaginganddecisionmaking. Now-a-daysthisispossibleina veryshortspanoftimewiththedevelopmentof sophisticatedcomputerhardwareandsoftware. Therefore,GISisacomputerbasedinformationsystem whichattachesavarietyofqualitiesand characteristics to geographicallocation (Fig.5)and helps in planning and decision making. A Geographic Information System(GIS) may bedefined in different manners. International Training Centre (ITC), Holland defined Geographic Information System (GIS) as a computerisedsystem thatfacilitatesthephasesof dataentry,dataanalysisanddatapresentation especially incases when we are dealing with geo referenced data.

IndianSocietyofGeomatics(ISG)andIndianSpaceApplicationCentre(ISRO)definedGIS as asystem whichprovidesacomputerisedmechanism forintegratingvariousgeoinformationdata sets and analysing themin order to generate information relevant to planning needs in a context. According to Centre for Spatial Database Management and Solutions (CSDMS), GIS is a computerbasedtoolformappingandanalysingthingsthatexistandeventsthathappenone earth.

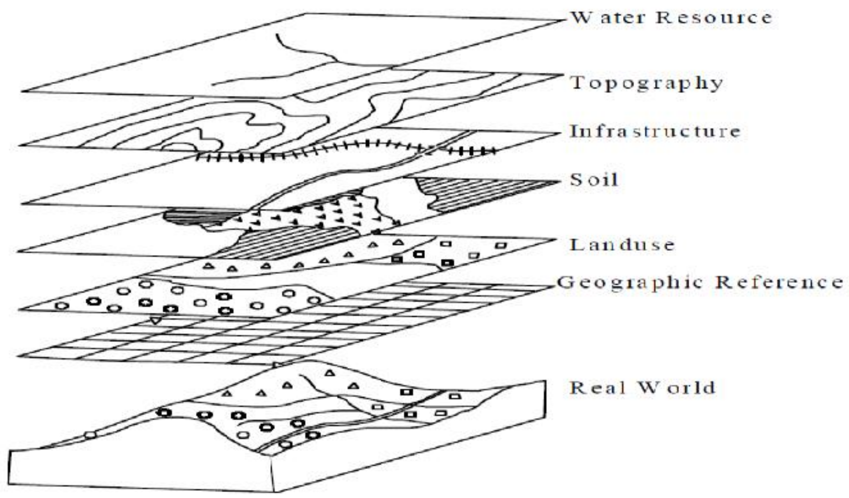


Fig 4.1 Layers

Burrough(1986)definedGISasasetoftoolsforcollecting,storing,retrievingatwill,transformingand displaying spatial data fromthe real world for a particular set of purpose.

Arnoff(1989)definedGISasacomputerbasedsystem thatprovidesfoursetsofcapabilities to handlegeoreferenced data,viz.datainput,datamanagement(datastorageandretrieval), manipulation analysis and data output.

Fromtheabovedefinitions,wecanconcludethataGISuserexpectssupportfromthesystem to enter geo referenced data to analyse it in various ways and to produce output (maps and other) fromthedata. GISdrawsonconceptsandideasfrommanydifferentdisciplines,suchas cartography,congitivescience,computerscience, engineering,environmentalsciences,geodesy, landscape architecture, law, photogrammetry,publicpolicy,remotesensing,statisticsand surveying. So,itinvolvesnotonlythestudyofthefundamentalissuesarisingfrom thecreation, handling,storageanduseofgeographicinformation, but it also examines the impacts of GIS on individuals and society and the influences of society on GIS.

4.1.1 DEVELOPMENT OF GIS

Keepinglongtraditionofmapmakingasbackground,G.I.S. hasbeendevelopedduring mid20th centurywiththedevelopmentofcomputerscience.Thedataanalysisof geographic locations was being done by computers in government organizations and universities in U.S.A. during 1950s and 1960s. The first true operational G.I.S. was developed by Dr. Roger Tomlinson, Department of Forestry and Rural Development , Canada. It was called as Canada GeographicInformationSystem(CGIS)andwasusedtostoreanalyseandmanipulateland relateddata.Dr.RogerTomlisonwasalsoknownasthe'FatherofG.I.S'.In1964,alaboratory ofComputerGraphicsandSpatialAnalysiswasestablishedattheHarvardGraduateSchoolof

Design by Howard T. Fisher. Thisorganizationdevelopedanumber of importanttheoretical conceptsofspatialdatahandlingandin1970sit distributed seminal software code and system such as 'SYMAP', 'GRID' and 'ODYSSEY'. This inspired subsequent commercial development.Byearly1980s,M&SComputing(laterIntergraph)and EnvironmentalSystems ResearchInstitute(ESRI)emergedascommercialvendorsofG.I.S.software.ESRIreleased ARC/InfoandARCViewsoftwarein1981and1992respectively.Bytheendof20thCentury, thedevelopmentofARCViewenabledviewingG.I.S.datathroughinternetandeliminated manyofthehardwareandlicensingexpensesof softwarepackages.Sincethenanumberof organisations anduniversitieshavebeendoingresearchinthefieldofG.I.S.anddeveloping user friendly softwares . Now there is a growingnumberoffree,opensourceG.I.S.packages which run in a wide range of operating systems and performspecific tasks.

4.1.2 REQUIREMENT OF GIS

Primarilydealswithgeographicdatato beanalysed,manipulatedandmanagedinan organized manner through computers to solve real world problems. So, GIS operation requires two things – computer systemand geographic data.

4.1.3 COMPUTER SYSTEM

Itincludesbothhardwareandsoftware. GISrunsthroughcomputersystemrangingfrom portablepersonalcomputers(PCs)tomulti-usersupercomputerswhichareprogrammedby widevarietyofsoftwarelanguages. Inallranges,thereareanumberthings,thatareessentialfor effectiveGISoperation. Theseinclude:1)aprocessorwithsufficientpowertorunthesoftware, 2)sufficient memory forthe storage of large volumeofdata,3)agoodquality,highresolution

colour graphic screen and 4)data input and output devices (for example digitizers, scanners, keyboard, printers and plotters).
There are a wide range of software packages for GIS analysis, each with its own advantages and disadvantages. Eventhoselistsaretoolongtobementionedhere,theimportantonesare different versions of ARC View, ARC Info, Map Info., ARC GIS, Auto Cad Map etc.

4.2 MAPS DEFINITION

A map is a set of points, lines and areas that are defined by their spatial location with respect to a coordinate system and by their non-spatial attributes‖ (Burrough 1986). A map legend links the non-spatial attributes to spatial attributes.

Types of Maps

There are three different types of maps, they are :

(i) General – purpose maps

They do not show any feature with special emphasis – they usually show roads, power lines, transportation routes, water features etc.

(ii) Special Purpose Maps

They are made for specific purposes such as ocean charts for navigation, cadastral maps to show property ownership details. They are usually of a large scale, which means a smaller portion of the earth.

(iii) Thematic maps

A map, which has a particular geographic theme. In a GIS the roads, rivers, vegetation, contour elevations etc, are categorized separately and stored in different map themes or overlays.

There are two different types of thematic maps, they are :

(i) A choropleth Map

A choropleth map contains different zones. The different zones are used to represent the different classes present in a theme for example,
Theme : census tracts class : average income, percentage, female populations, mortality rate etc.

(ii) An isopleth Map

An isopleth map is a map, which contains imaginary lines used to connect points of equal values. (Isolines) They may be contours in the case of a topographic map. Similarly maps can be drawn for variables such as temperatures, pressure, rainfall and population density.

Uses of Maps

1. Maps have been around since ancient times where they were originally used for navigation and military purposes.
2. Maps are used to organize geographic data. The geographic data are :
   - **A. Topography**
     General in nature.
   - **B. Natural resources**
     —Thematic maps‖ , contains information about a specific subject or theme (geology, soils, roads, ecology, hydrology… etc.).
   - **C. Political**
     —Abstract‖ boundaries for public, private, national and international lands.
   - **D. Information types**
     Qualitative – land use classes.
     Quantitative – depth to

bedrock.

Characteristics of Maps

The following are the characteristics of maps, they may be of any type but they all have the same characteristics.

1. Maps are always concerned with two elements of reality
   a) One is the location, which is the special data.
   b) The attributes concerned with it, which are referred to as a spatial or non spatial data..
2. Maps are usually outdated representations. This is because yesterday‘s reality need not be true today also.
3. Maps are always static versions i.e., they are permanent prints on paper, in which alterations or changes cannot be made.
4. Maps cannot be updated with the same version in other words, updating a map involves the preparation of a new map.
5. Maps are always drawn to some scale, smaller the scale more detailed will be the map.

4.3 MAP PROJECTIONS

A projection is a method by which the curved surface of the earth is represented on a flat surface and it involved the use of mathematical transformations between the location of places on the earth and their projected locations on the plane. A map projection is anytransformation between the curved reference surface of the earth and the flat plane of the map.

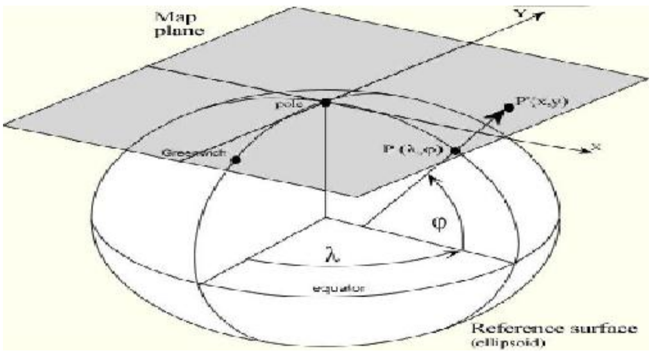


Fig 4.2 Map projections

For each map projection the following equations are available:

X,Y = f (j, l) *Forward equation*

j, l = f (X,Y) *Inverse equation*

The **forward equations** are used to transform geographic coordinates - latitude (j) and longitude (l) - into Cartesian coordinates (X,Y), while the **inverse equations** of a map projection are used to transform Cartesian coordinates into geographic coordinates

Properties of Map Projections

The following properties would be present on a map projection without any scale distortions:
Areas are everywhere correctly represented

All distances are correctly represented.
All directions on the map are the same as on Earth
All angles are correctly represented.
The shape of any area is correctly represented

General projections Classified as folloes:
EQUAL AREA PROJECTIONS: An **equivalent** map projection, also known as an **equal-area** map projection, correctly represents areas sizes of the sphere on the map. Conformal projections:

A **conformal** map projection represents angles and shapes correctly at infinitely small locations.

EQUIDISTANT PROJECTIONS:They represent the distances to places from one or two points. Types of projection

Universal Transverse Mercator (UTM),
Transverse Mercator (also known as Gauss-Kruger),
Polyconic

4.3.1 POLYCONIC PROJECTION

It is used to project for preparing world map.

In this projection all parallels are projected without any distortion, which means scale is exact along all parallels. Scale is exact along the central meridian also.

1. The projection is called polyconic as many cones are involved to make all parallels exact.

Transverse Mercator Project it is used to project near the pole regions.

This widely used conformal projection was invented by mathematician and cartographer Johnn Heinrich Lambert in 1772. Carl F. Gauss analysed the projection in 1882 and L. Kruger completed the development of the projection by developing the formulae further in order to be suitable for numerical calculations in 1912. This is a beautiful example or creating for malising – implementing, all three processes taking over a century time.

1. A policy decision for a gradual switch over. Both, transverse mercator and conformal conic projection with two standard parallels, are suitable and do not have the drawbacks mentioned in respect of polyconic projection. Suitable zones of $6^0 x 6^0$ or $8^0 x 8^0$ or statewise can be designed. All maps from village to subdivision to taluka to district to state on various scales can be on the same projection within a particular zone.

Universal Transverse Mercator Projection UTM) It is used to project near the equator regions.

The Universal Transverse Mercator Projection is a particular case of transverse mercator projection. This is a world wide plane coordinate system brought up by the military during World War II. This was adopted by the U.S. Army in 1947 for designating rectangular coordinates on large scale military maps of the entire world.

4.4 MAP ANALYSIS

There are mainly four key activities that any urban planners or scientists orresource managers and others use geographic information for. They observe and measure environmental parameters and develop maps which portray characteristics of the earth. They monitor changes in our surroundings in space and time. In addition, they model alternatives of actions and process operation in the environment. These, four activities are Measurement, Mapping, Monitoring and Modelling termed as key activities which can be enhanced by the using information systems.

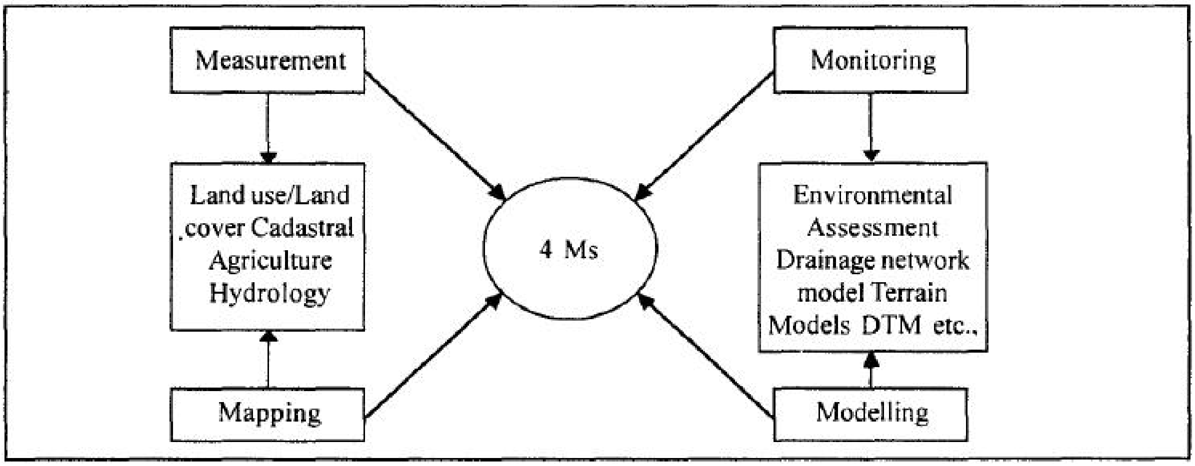


Fig 4.3 Map Analysis

GIS technology is more different from traditional mapping and map analysis.GIS is based on a mathematical framework of primitive map analysis operations analogous to those of traditional statistics and algebra. From this perspective, GIS forms a toolbox for processing maps and fundamental concepts for spatial measurement. It provides a foundation for advanced analytic operations involving spatial analysis and measurement. Most of GISs contain analytic capabilities forreclassifying and overlaying maps. Any GIS system for the measurement of areas, distances, angles and and so on requires two components, namely, a standard measurement unit and a measurement procedure. Another major function of GIS capability is the study of environmental surroundings and the monitoring of environmental parameters (Burrough et ai, 1988). Although analytical models have been linked to GIS for spatial measurement and resource assessment, the cross fertilisation between the modules of modelling, measurement and automated mapping allows the GIS user to monitor the environment· and the earth system. In principle, it is possible to make a clear distinction between GIS and digital cartography. Mapping technology or digital cartography deals with map features and with associated attributes of colour, symbology, name of annotation, legends, neatlinesand north arrows. GIS includes the capabilities for storing, editing, and handling the relationships of attributes with their spatial entities along with the capabilities of digital cartography. A map, an ultimate product of digital cartography or GIS, is a very persuasive form of data display and a computer drawn map carries the authority of a powerful technology. GIS applications now span a wide range, from sophisticated analysis and modelling of spatial data to simple inventory and management. They also dictate the development directions of much of the industry. However, several vendors have chosen to concentrate on the niche market for environmental applications and to emphasise support for environmental modelling. GRASS is a Significant public domain GIS software developed by USA with substantial capabilities for modelling.

4.4 DEFINITIONS OF GIS

The tool-base definition of a GIS is a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purpose.

(a) Toolbox – based definitions

A powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world. A system for capturing, storing, checking, manipulating, analyzing and displaying data which are spatially referenced to the Earth. An information technology which stores, analyses, and displays both spatial and non-spatial data.

b) Data base definitions

A database system in which most of the data are spatially indexed, and upon which a set of procedures operated in order to answer queries about spatial entities in the database. Any manual or computer based set of procedures used to store and manipulated geographically referenced data.

c) Organization – based definitions

An automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data.

4.4.1 DEVELOPMENT OF GEOGRAPHICAL INFORMATION SYSTEMS

In the late twentieth century, demands for data on the topography and specific themes of the earth‘s surface, such as natural resources, have accelerated greatly. Stereo aerial photography and remotely sensed imagery have allowed photogrammetrists to map large areas with great accuracy. The same technology also gave the earth resource scientists – the geologist, the soil scientist, the ecologist, the land use specialist – enormous advantages for reconnaissance and semi – detailed mapping.

The need for spatial data and spatial analyses is not just the preserve of each scientists.

Urban planners and cadastral agencies need detailed information about the distribution of land and resources in towns and cities.

Civil engineers need to plan the routes of roads and canals and to estimate construction costs, including those of cutting away hillsides and filling in valleys. Police departments need to know the spatial distribution of various kinds of crime, medical organizations

Epidemiologists are interested in the distribution of sickness and disease, and Commerce as interested in improving profitability through the optimization of the distribution of sales outlets and the identification of potential markets.

The enormous infrastructure of what are collectively known as ‗utilities‘-that is water, gas, electricity, telephone lines, sewerage systems – all need to be recorded and manipulated as spatial data linked to maps.

About 15,500 years ago on the walls of caves near Lascaux, France, Cro-Magnon hunters drew pictures of the animals they hunted. Associated with the animal drawings are track lines and tallies thought to depict migration routes.

In 1854, John Snow depicted a cholera outbreak in London using points to represent the locations of some individual cases, possibly the earliest use of the geographic method.[4] His study of the distribution of cholera led to the source of the disease, a contaminated water pump (the Broad Street Pump, whose handle he disconnected terminating the outbreak) within the heart of the cholera outbreak.

The year 1967 saw the development of the world's first true operational GIS in Ottawa, Ontario, Canada by the federal Department of Forestry and Rural Development. Developed by Dr. Roger Tomlinson, it was called the "Canada Geographic Information System" (CGIS) and was used to store, analyze, and manipulate data collected for the Canada Land Inventory (CLI)—an initiative to determine the land capability for rural Canada by mapping information about soils, agriculture, recreation, wildlife, waterfowl, forestry, and land use at a scale of 1:50,000. A rating classification factor was also added to permit analysis.

CGIS was the world's first "system" and was an improvement over "mapping" applications as it provided capabilities for overlay, measurement, and digitizing/scanning. It supported a national coordinate system that spanned the continent, coded lines as "arcs" having a true embedded topology, and it stored the attribute and locational information in separate files. As a result of this, Tomlinson has become known as the "father of GIS," particularly for his use of overlays in promoting the spatial analysis of convergent geographic data CGIS lasted into the 1990s and built the largest digital land resource database in Canada. It was developed as a mainframe based system in support of federal and provincial resource planning and management. Its strength was continent-wide analysis of complex datasets. The CGIS was never available in a commercial form.

By the early 1980s, M&S Computing (later Intergraph), Environmental Systems Research Institute (ESRI) and CARIS (Computer Aided Resource Information System) emerged as commercial vendors of GIS software, successfully incorporating many of the CGIS features, combining the first generation approach to separation of spatial and attribute information with a second generation approach to organizing attribute data into database structures. In parallel, the development of two public domain systems began in the late 1970s and early 1980s. MOSS, the Map Overlay and Statistical System project started in 1977 in Fort Collins, Colorado under the auspices of the Western Energy and GRASS GIS was begun in 1982 by the U.S. Army Corps of Engineering Research Laboratory (USA-CERL) in Champaign, Illinois, a branch of the U.S. Army Corps of Engineers to meet the need of the United StatesMilitary for software for land management and environmental planning. The later 1980s and 1990s industry growth were spurred on by the growing use of GIS on Unix workstations and the personal computer. By the end of the 20th century, the rapid growth in various systems had been consolidated and standardized on relatively few platforms and users were beginning to export the concept of viewing GIS data over the Internet, requiring data format and transfer standards. More recently, there are a growing number of free, open source GIS packages which run on a range of operating systems and can be customized to perform specific tasks.

4.5 BASIC COMPONENTS OF GIS

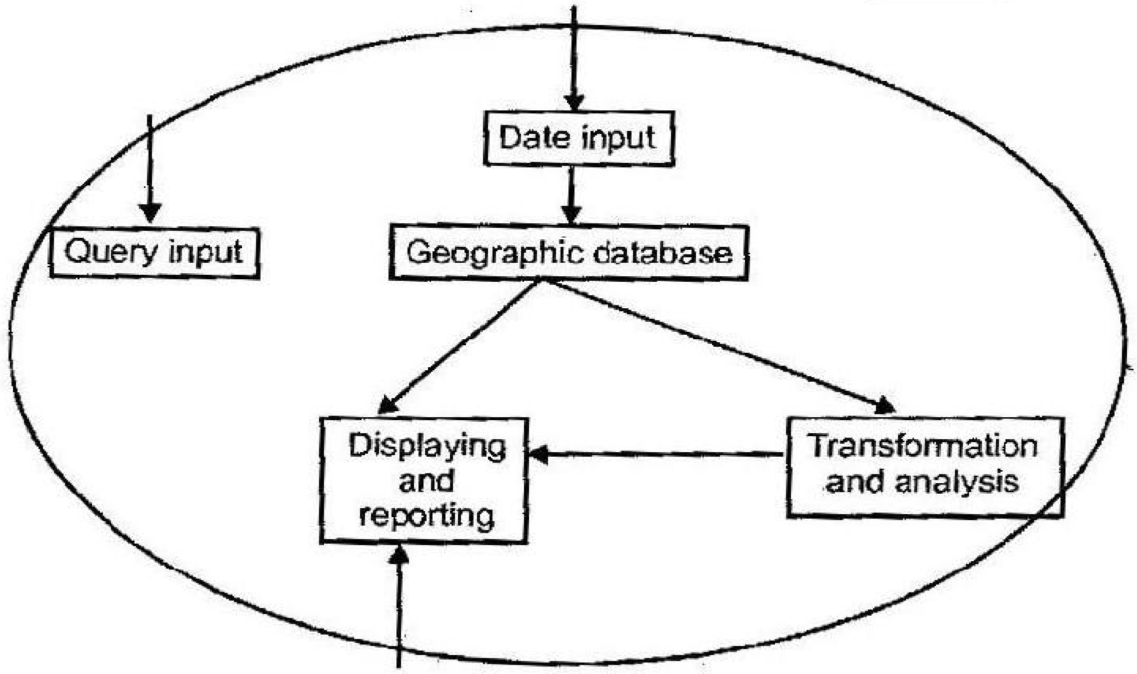


Fig 4.4 Components of GIS

Geographic information systems have three important components they are
(i) Computer hardware
(ii) Set of application software modules.
(iii) And a proper organizational contest.

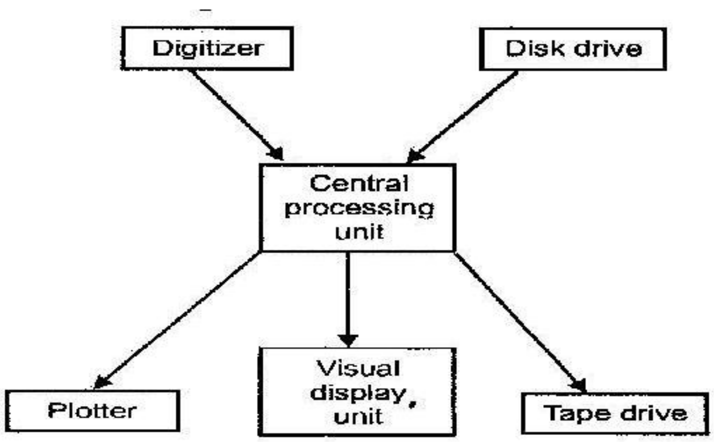


Fig 4.5 Components of GIS

4.5.1 HARDWARE COMPONENTS OF A GIS

The general hardware components of a GIS are shown in the figure

CPU –Central processing unit is linked to disk drive, which provides space for storing dataand programs.

Digitizer –It is a device used to convert data from maps and documents into digitalform (Raster to Vector).

Plotter –Plotter is used to present the results of the data processing on a paper.

Tape drive –It is used to store data or programs on magnetic tape for communicatingwith other systems.

VDU (Visual Display Unit)–It is used to control the computer and the otherperipherals. It is otherwise known as terminal or workstation.

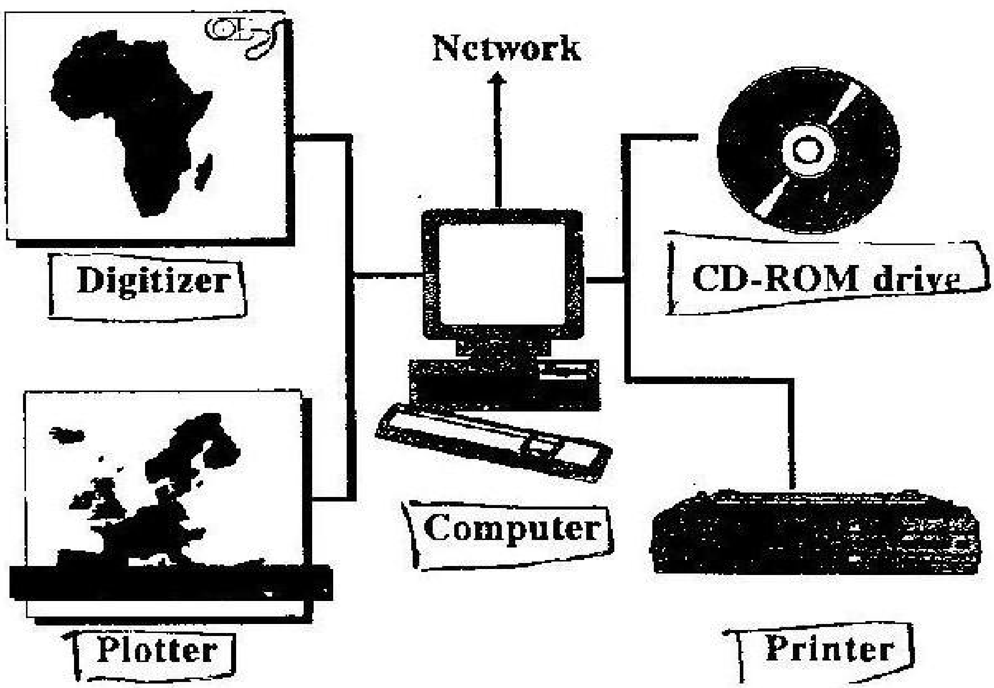


Fig 4.6 Hardware components of GIS

4.6 STANDARD GIS SOFTWARE

Arc info

Arc info was developed by Environmental Systems Research Institute (ESRI), Redlands, California, USA.Arc Info data structure Arc Info is a vector- based GIS package, capable of handling both spatial and non-spatial data. It organizes geographical data using vector topological models and non-spatial data using relational models in a DBMS. The arc node and polygon topology are organized to identify points, lines, and polygon relations. The cartographic data are then linked to the attribute data through a link item.

Arc Info functionalities : Arc Info has a wide range of functions which have been developed based on a tool-box concept -where each function can be visualized as a tool and having a specific utility. The major modules of Arc Info functionalities are :

(a) ADS and ARCEDIT: data base creation in Arc Info is possible through the process of digitisation using the Arc Digitising System(ADS) and the ARCEDIT module. ARCEDIT is a powerful editing utility having capabilitiesfor feature -based editing. These modules include the functions for coordinate entry using different devices - digitisers, screen cursors and so on;

(b) INFO: INFO is the manager for tabular data associated with geographic features in map coverage of Arc Info. INFO provides facilities for data definition of data files, use of existing data files, data entry and update and, sorting and querying;

(c) Analysis Modules: Arc Info offers spatial overlay capabilities based on topological overlay concepts. Union/ intersect overlays, buffer generation, proximity analysis, feature aggregation, feature extraction, transformation, nearness functions and other integration utilities are available;

(d) ARCPOLT: This module has capabilities for generating cartographic quality outputs from the database. This includes utilities for interactive map composition, editing map compositions, functionality, the incorporation of coverage features to the required scale, generalisation, symbolisation, transformation, and so on. Placement of non-coverage features, include legends, free text, and logos, graphic elements.

(e) TIN: The TIN module of Arc Info can be used to create, store, manage, and perform analysis pertaining to the third dimension data. The modeling capabilities include calculation of slope, aspect, isolines or contouring range estimation, perspectives, and volumes. Additional functions for determining spatial visibility zones and line of sight are also provided;

(f) NETWORK: The NETWORK module of Arc Info performs two general categories of functions: network analysis and address geocoding. Network analysis is p05sible for optimal path determination and resource allocation analysis. The geocoding module allows for associating addresses to line networks and determining the spatial framework of addresses in an application;

(g) COGO: It is the coordinate geometry module of Arc Info; supports the functions performed by land surveyors and civil engineers for the design and layout of sub-divisions, roads and related facilities, as well as the special plotting requirements. COGO allows definition, adjustment and close traverse including adding curves on a traverse; it computes area, bearing and azimuths;

(h) GRID is a raster-based module of Arc Info. GRID has an interface to Arc Info, so coverage can be converted to GRID and from GRID to Arc Info. GRID supports powerful modeling tools of raster integration, potential mapping, spread/grow operations and so on.

Arc Info also supports ERDAS system, OEM data, Autocad -DXF format, IGES format and a flat file format. ARCVIEW module is a desktop mapping package oriented towards viewing and querying Arc Info databases.

GIS MAPPER : It is the basic module for data entry to create a data base of maps by generation and editing of the vector database, which forms the base for subsequent raster -based analysis. It includes Planner, for quick interactive report generator. GIS MAPPER also supports pen plotter output to several plotters;

ANALYSER : This module allo~s the user to perform data conversion forpolygonisation: raster creation from the v~ctor boundaries of the polygonal areas , overlay operations for two or more polygonal overlays to generate another level of output, proximity analysis, and corridor analysis around specified map features

TOPOGRAPHER: This is for processing of three dimensional data and Dem. Different products like slope, aspect, perspective views, and volume calculations can be derived from this module;
INTERPRETER: This is for importing remotely sensed images from digital image analysis system in to the PAMAP GIS as surface covers.
MODELLER : This module integrates multiple -surface rasters or multiple data base attributes to make planning decisions quickly and accurately. It has three main functions - combination of modeling, regression analysis and correlation, and covariance analysis;
NETWORKER : This module is used to create, analyse, and manage networks.
FILE TRANSLATOR: This is for importing and processing map files created in various data formats like IGDS, SIF (Intergraph), DLG and DXF (Autocad).
PAMAP platforms : This is available on variety of platforms -on pentium 486 PCs; UNIX workstations and VAX systems and also on MS Windows with multitasking capability.

4.7 DATA TYPES

4.7.1 SPATIAL DATA

Spatial data (mapable data) of geo-referenced data is commonly characterized by the presence of two fundamental components.

(i) The physical dimension or class i.e., the phenomena being reported.
For example : Height of the forest canopy, demographic class, rock type, regetation type details of a city etc.

(ii) The spatial location of the phgenomena
For example : Specified with reference to common coordinate system (latitude and longitude etc).

4.7.2 NON SPATIAL / ATTRIBUTE / A SPATIAL OR TABULAR DATA

1. There are usually data tables that contain information about the spatialcomponents of the GIS theme. These can be numeric and/or character data such as timber type, timber volume, road size, well depth etc. The attributes are related back to the spatial features by use of unique identifiers that are stored both with the attribute tables and the features in each spatial data layer. Attributes can be either qualitative (low, medium, high income) or quantitative (actual measurements). The database allows us to manipulate information in many ways : from simple listing of attributes, sorting features by some attributes, grouping by attributes, or selecting and singling out groups by attributes.

4.8DBMS (DATA BASE MANAGEMENT SYSTEMS)

The data bases used in GIS are most commonly relational. Nevertheless, Object Oriented data bases are progressively incorporate**d.**

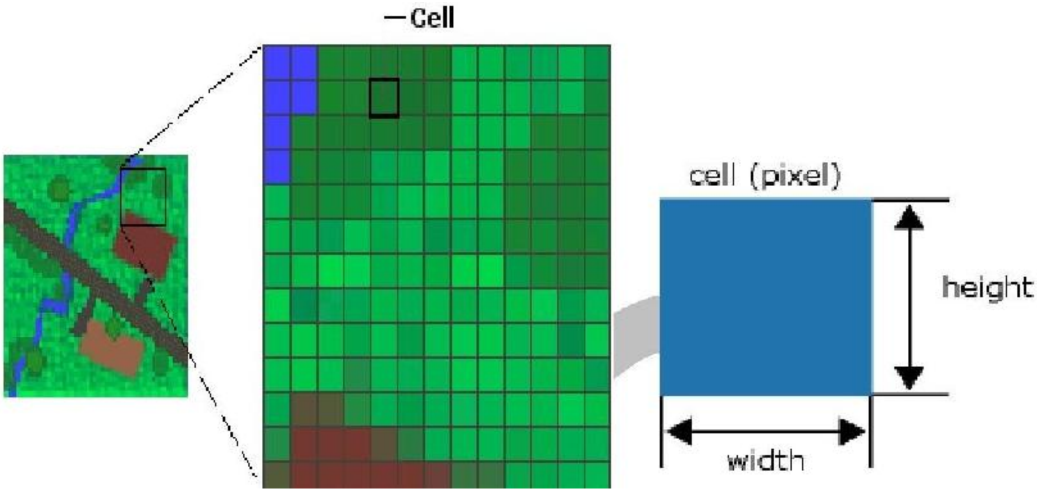


Fig 4.6 DBMS

4.8.1 Hierarchical database

A **hierarchical database** is a kind of database management system that links records together in a tree data structure such that each record type has only one owner, e.g. an order is owned by only one customer. Hierarchical structures were widely used in the first mainframe database management systems. However, due to their restrictions, they often cannot be used to relate structures that exist in the real world. Hierarchical relationships between different types of data can make it very easy to answer some questions, but very difficult to answer others. If one-to-many relationship is violated (e.g., a patient can have more than one physician) then the hierarchy becomes a network.

Field - smallest unit of data

Segment - groups of fields; nodes of the tree structure

Data base record - a collection of related segments; a particular tree structure Data base - composed of database records

Data base description - how data base records are defined; set of assembly-language macro instructions
Root - first segment

Sequence field - one field in each segment used to order the occurrences of a given type

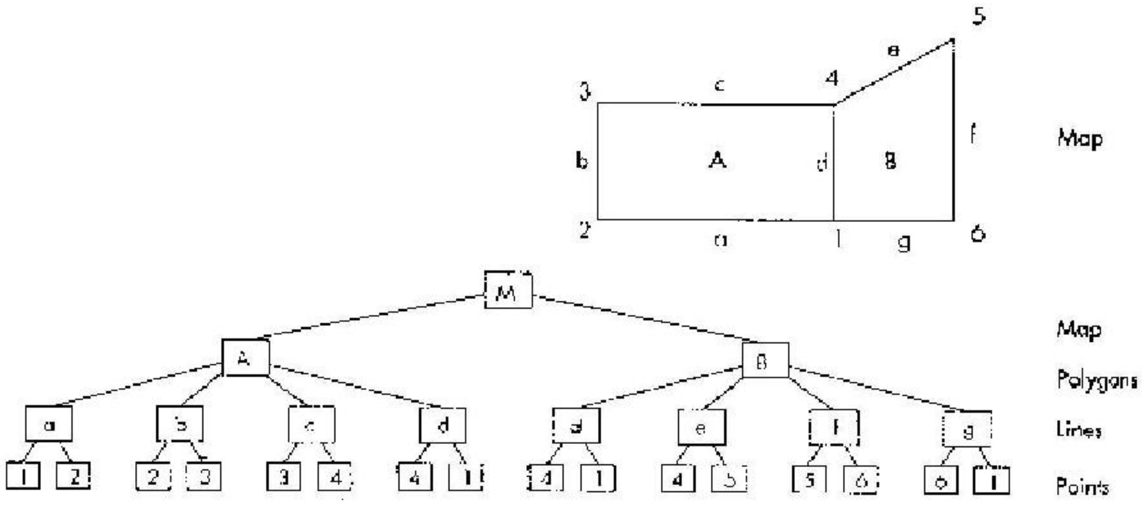


Fig 4.7 Hierarchical Data Case

4.8.2 NETWORK MODEL

A **network model** database management system has a more flexible structure than the hierarchical model or relational model, but pays for it in processing time and specialization of types. Some object-oriented database systems use a general network model, but most have some hierarchical limitations.

The neural network is an important modern example of a network database - a large number of similar simple processing units, analogous to neurons in the human brain, 'learn' the differences and similarities between a number of inputs.

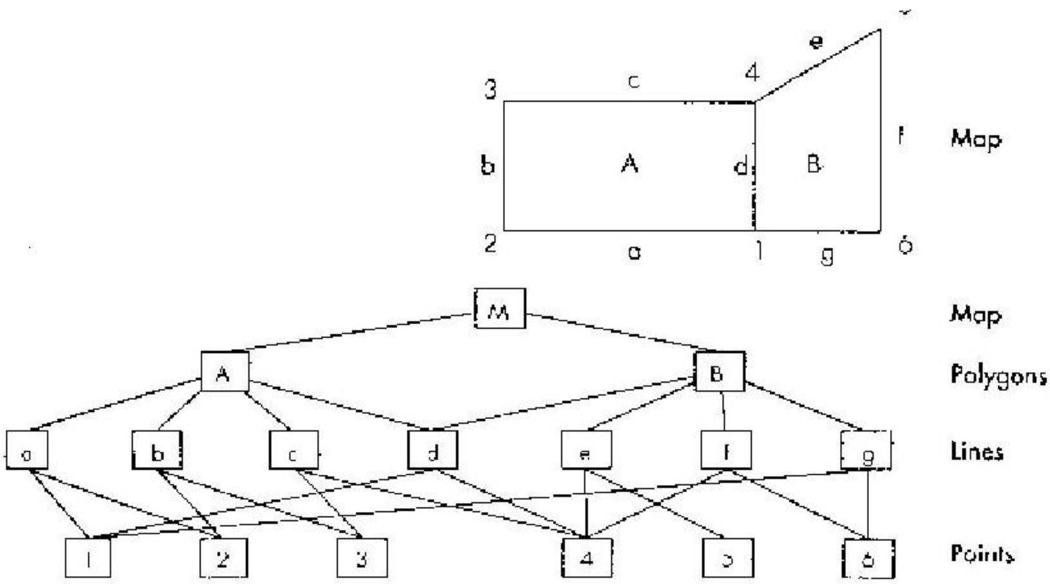


Fig 4.8 Network model

4.8.3 Relational data bases

In a relational data base, data is stored in tables where rows represent the objects or entities and columns the attributes or variables. A data base is usually composed of several tables and the relations between them is possible through a common identifier that is unique for each entity. Most of the relational data bases in GIS present two variables with identifiers; one ofthem is unique and correlative, it could be numeric or alphabetic, and the second one might be repeated and helps to organize the attribute table.

The advantages of using this kind of data base are:

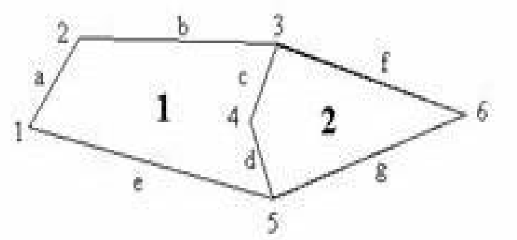
The design is based in a methodology with heavy theoretical basis, which offers confidence in its capacity to evolve.
It is very easy to implement it, specially in comparison with other models such as hierarchical, network, and object oriented

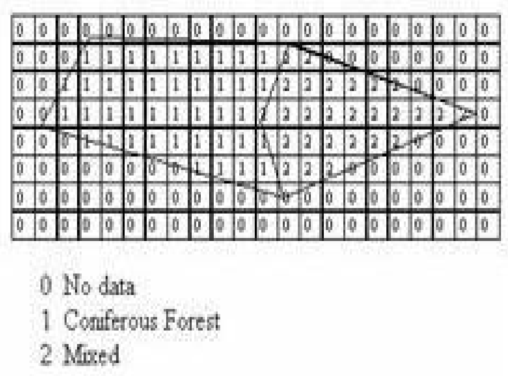
It is very flexible. New tables can be appended easily.

Finally, many powerful DBMS using this approach contains query languages (like SQL) which makes easy to include this tool in a GIS. Thus, some commercialised GIS packages include a DBMS pre- existent.

4.8.4 OBJECT ORIENTED DATA BASES

Based on objects, it can be defined as an entity with a localisation represented by values and by a group of operations. Thus, the advantage in comparison with relational data bases is based on the inclusion, in the definition of an objet, not only its attributes but also the methods or operations that act on this object. In addition, the objects belong to classes that can have their own variables and these classes can belong to super-classes.





Link	Right Polygon	Left Polygon	Node 1	Node 2
a	1	0	1	2
b	1	0	2	3
c	1	2	3	4
d	1	2	4	5
e	0	1	1	5
f	2	0	3	6
g	2	0	6	5

Polygon	Owner	Landuse
1	Forestry Commission	Coniferous Forest
2	Forestry Commission	Mixed

Fig 4.9 Object oriented Data Base

A simple, unstructured, unordered list of data records.
Easy to construct, but inefficient to access and retrieve.

For a simple flat file with *n* records, *(n+1)/2* search operations are required to find a record.

2). Ordered Sequential Files

Records are organized as a sequential list according to alphabetic order or other criteria.

Only *LOG2(n+1)* searching operations are required to find a record from the file if divide-and-conquer searching method is used.

3). Indexed files

Easy to find a specific record with associated, cross-referenced attributes.

The index is used to quickly find a particular type of information in a larger file by selecting key features that can be searched for

Direct index file

Inverted index files

CHAPTER 5
DATA ENTRY, STORAGE AND ANALYSIS

5.1 DATA MODELS VECTOR AND RASTER DATA

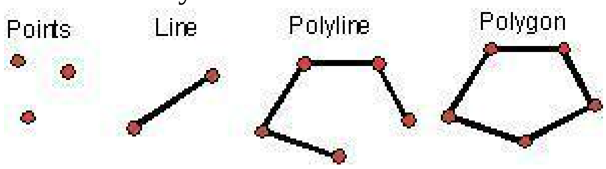
A vector based GIS is defined by the vectorial representation of its geographic data. The most common representation of map is using vector date that is consist of point, line and polygon

5.1.1 VECTOR DATA

i. Point Data -- layers described by points (or "event") described by x,y (lat,long; east, north)

ii. Line/Polyline Data -- layers that are described by x,y points (nodes, events) and lines (arcs) between points (line segments and polylines)

iii. Polygon Data -- layers of closed line segments enclosing areas that are described by attributes



Polygon data can be "multipart" like the islands of the state of Hawaii.

Vector Data Structures

• Fundamental unit is the x, y coordinate (***vertex***)

– points are explicitly defined

– lines, arcs and polygons are constructed

• Map area is presumed continuous

– position can be defined with great precision; limited by precision of software/hardware and source data

• Usually provides finer spatial resolution than raster model

Point

A zero-dimensional abstraction of an object represented by a single X,Y co-ordinate. A point normally represents a geographic feature too small to be displayed as a line or area; for example, the location of a building location on a small-scale map, or the location of a service cover on a medium scale map.

Line

A set of ordered co-ordinates that represent the shape of geographic features too narrow to be displayed as an area at the given scale (contours, street centrelines, or streams), or linear features with no area (county boundary lines). A lines is synonymous with an arc.

Polygon

A feature used to represent areas. A polygon is defined by the lines that make up its boundary and a point inside its boundary for identification.Polygons have attributes that describe the geographic featurethey represent.

5.1.2 RASTER DATA

Consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.

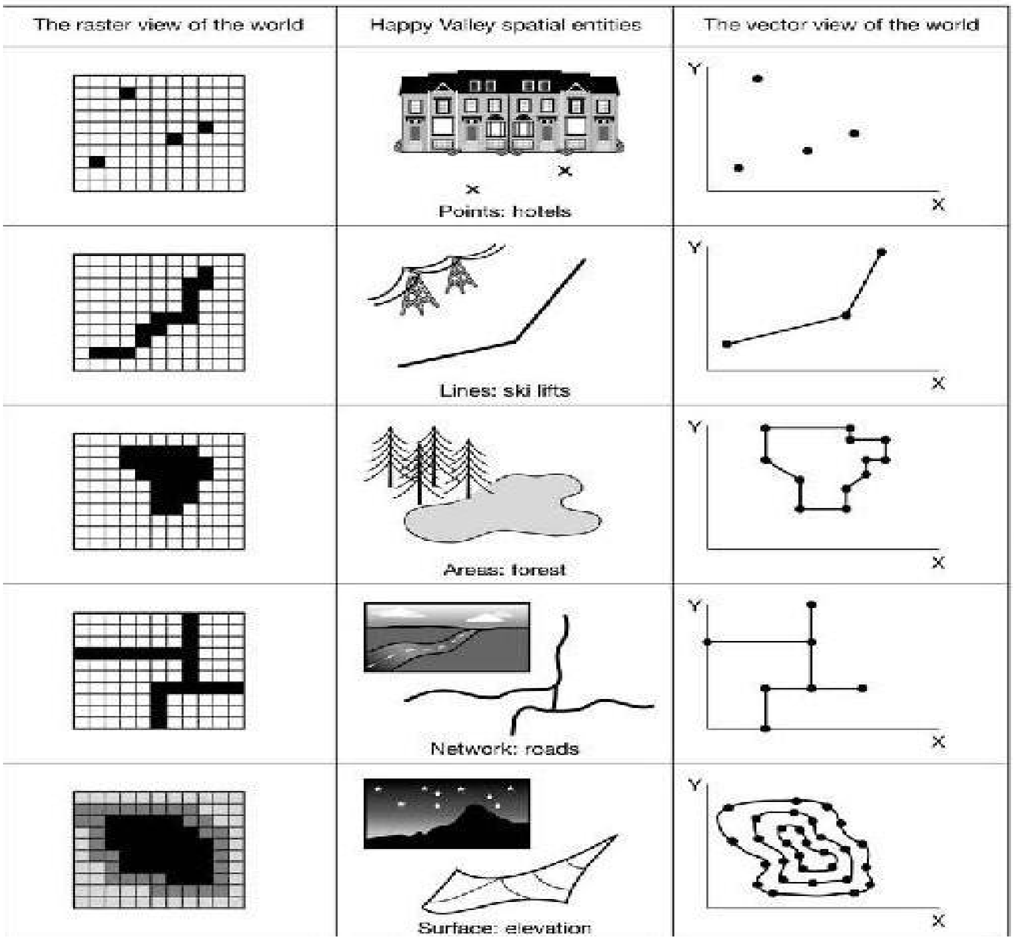


Fig 5.1 Raster and Vector Data

5.2 DATA COMPRESSION:

Data compression of Network GIS refers to compression of geospatial data within a network GISso that volume of data transmitted across the network can be reduced. Typically, a properly chosen compression algorithm can reduce data size to 5~10% of original for images [1-2], and 10~20% for vector [3] and textual data [4]. Such compression ratios result in significant performance improvement.

Data compression algorithms can be categorized into lossless and lossy. Bit streams generated by lossless compression algorithm can be faithfully recovered to the original data. If loss of one single bit may cause serious and unpredictable consequences in original data (for example, text and medical image compression) lossless compression algorithm should be applied. If dataconsumers can tolerate distortion of original data to a certain degree, lossy compressionalgorithms are usually better because they can achieve much higher compression ratios than lossless ones

Data compression of network GIS is similar to other data compression algorithms on distributed computing platforms. Image compression algorithms such as JPEG had been applied since the first Web-based GIS emerged in 1993. However, the compression of vector data is introduced much later, such as the Douglas-Peuker algorithm and the work done in 2001 by Bertolotto and Egenhofer.

5.2.1 SCIENTIFIC FUNDAMENTALS

Data compression originates from information theory, which concentrates on systematicresearch on problems arising when analog signals are converted to and from digital signals and digital signals are coded and transmitted via digital channels. One of the most significant theoretical results in information theory is the so-called source coding theorem, which asserts that there exists a compression ratio limit that can only be approached but never be exceeded by any compression algorithms. For most practical signals it is even very difficult to obtain compression algorithms whose performance is near this limit. However, compression ratio is by no means the unique principal in the development of compression algorithm. Other important principals include fast compression speed, low resource consumption, simple implementation, error resilience, adaptability to different signals, etc.

5.3 DATA INPUT BY DIGITIZATION SCANNING

The data to be input for GIS are typically acquired in a diverse variety of forms.Some data come in graphic and tabular forms. These would include maps and photographs, records from site visits by specialists, related to non-spatial information from both printed and digital files (including descriptive information about the spatial data, such as date of compilation, and observational criteria). Other data come in digital form. These would include digital spatial data such as computer records of demographic or land ownership data, magnetic tapes containing information about topography and remotely sensed imagery. The data to be input for GIS are of different forms. These include key board entry or key coding, digitising, scanning and digital data. The process of data encoding and editing is often called as data stream.

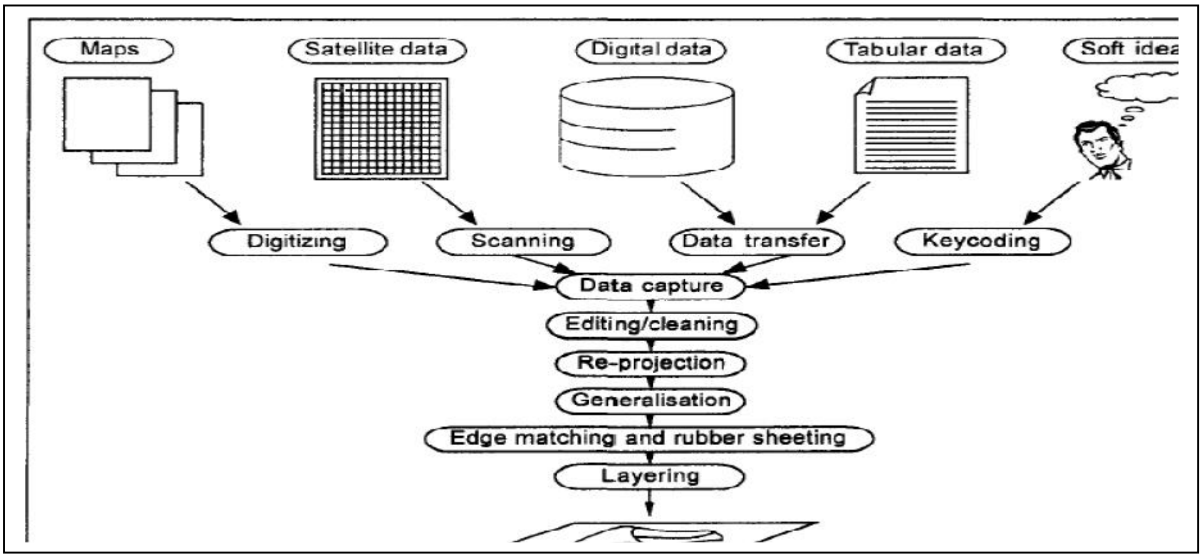


Fig 5.2 Data input methods

5.3.1 DATA INPUT METHODS

Before explaining the input methods, it is necessary to make a distinction between analogue (non-digital) and digital sources of spatial data. Analogue data are normally in paper form and include paper maps, tables of statistics and hardcopy aerial photographs. All these forms of data need to be converted to digital form before use in a GIS. Digital data like remote sensing data are already in compute-readable formats and are supplied on diskette, magnetic tape or CD-ROM or across a computer network. All data in analogue form need to be converted to digital form before they can be input into GIS. There are four methods of data input which are widely used: keyboard entry, manual digitising, automatic digitisation, and scanning. Digital data must be downloaded from their source media and may require reformatting to convert them to an appropriate format for the GIS being used. Reformatting or conversionmay also be required after analogue data have been converted to digital form. For example, after scanning a paper map, the file produced by the scanning equipment may not be compatible with the GIS, so it needs reformatting. For both the analogue anrJ digital data, keyboard entry method, manual digitising and automatic digitizing and scanning methods are very important as detailed below.

5.3.2 MANUAL DIGITISING

Manual digitising is the most common method of encoding spatial features frompaper maps. It is a process of converting the spatial features on a map into a digital format. Point, line, and area features that form a map, are converted into (x, y) coordinates. A point is represented by a single coordinate, a line by a string of coordinates, and, when one or more lines are combined with a label point inside an outline, then an area (polygon) is identified. Thus digitising is the process of capturing a series of points and lines. Points are used for two different purposes: to represent point features or to identify the presence of a polygon. Manual digitising requires a table digitiser that is linked to a computer work station (Fig 10.2). To achieve good results, the following steps are necessary. Before, discussing these steps, the description of digitisers is provided for the beginners in this field of technology. Digitisers are the most common device for extracting spatial information from maps and photographs. The position of an indicator as it is moved over the surface of the digitizing tablet is detected by the computer and interpreted as pairs of x, y coordinates. The indicator may be a pen-like stylus or a cursor. Frequently, there are control buttons on the cursor which permit control of the system without having to turn attention from **the** digitising tablet to a computer terminal. The current most popular digitiser is contemporary tablets using a gird of wires embedded in the tablet to a generate magnetic field which is detected by the cursor. The accuracy of such tables are typically better than 0.1 mm which is better than the accuracy with which the average operator can position the cursor. Sometimes the functions for transforming coordinates are built into the tablet and used to process data before it is sent to the host (Fig 10.2).

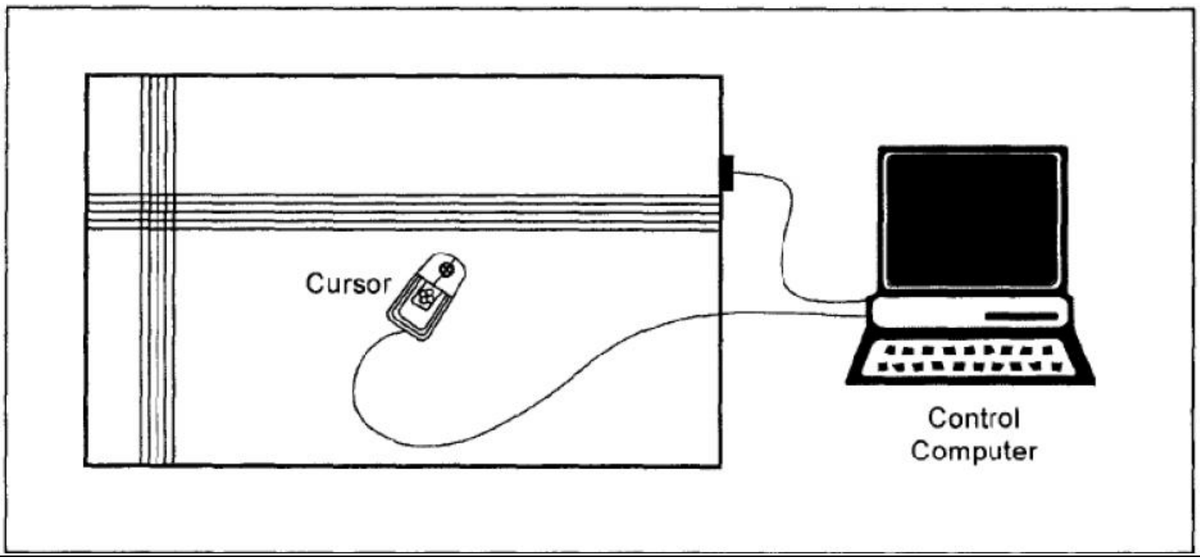


Fig 5.3 Manual Digitizing

5.3.3 THE DIGITIZING OPERATION

The map is affixed to a digitizing table. Three or more control points are to be identified and digitized for each map sheet. These points should be those that can be easily identified like intersections of major streets and prominent landmarks. The points are called reference points or tics or control points.

The coordinates of these control points will be known in the coordinate system to be used in the final data, such as, latitude and longitude. The control points are used by the system to calculate the necessary mathematical transformations to convert all coordinates to the final system. The more the control points, the better the accuracy of digitisation. Digitising the map contents can be done in two different modes: point mode and stream mode. **Point mode** is the mode in which the operator identifies the points to be captured explicitly by pressing a button, and **stream mode** is the mode in which points are captured at set time intervals, typically 10 per second, or on movement of the cursor by filed distance. Most digitizing is currently done in point mode.

Problems with Digitising Maps

The problems that come during the process of converting the maps into digital mode through the process of digitisation vary from one CAD operator to another. It depends upon the experience and skill of the operator and density of points, lines and polygons of the map. The accuracy of the output of the digitisation also depends upon the selection and distribution of the control points. Some of the commonly occurred problems during the digitisation of any paper map are as follows:

(i) Paper maps are unstable; each time the map is removed from the digitising table, the reference points must be re-entered when the map is affixed to the table again.

(ii) If the map has stretched or shrunk in the interim, the newly digitised points will be slightly off in their location when compared to previously digitised points.
(iii) Errors occur on these maps, and these errors are entered into the GIS data base as well.
(iv) The level of error in the GIS database is directly related to the error level of the source maps.
(v)Maps are meant to display information, and do not always accurately record vocational information.

A digital image of the map is produced by moving an electronic detector acrossthe map surface. The size of the map area viewed by the detector and scanning should be processed or edited to improve the quality and convert the raster to vector after online digitisation. The accuracy of the scanned output data depends on the quality of the scanner, the quality of the software used to process the scanned data, and the quality of the source document. A very important feature that a GIS user should observe after scanning the paper map is the occurrence of splines, which is black appearance on the scanned output. This can be removed by using a process called thinning.

The resolution of the scanner used affects the quality and quantity of outputdata. The cheaper flat-bed scanners have resolutions of 200-500 mm whereas the more expensive drum scanners use resolutions of 10-50 mm. The higher the resolution, the larger the volume of the data produced.

Scanning and Automatic Digitising

Scanning is the most commonly used method of automatic digitising. Scanning is an appropriate method of data encoding when raster data are required, since this is the automatic output format from most scanning software. Thus scanning may be used as a background raster dataset for the over-plotting of vector infrastructure data, such as, pipelines and cables.
A scanner is a piece of hardware Fig for converting an analogue source document to a digital raster format (Jackson Woodsford, 1997). There are two types of scanners, (i) Flatbed scanner and (ii) rotating drum scanners. The cheapest scanners are small flatbed scanners, and high quality and large format scanners are rotating drum scanners in which the sensor moves along the axis of rotation.

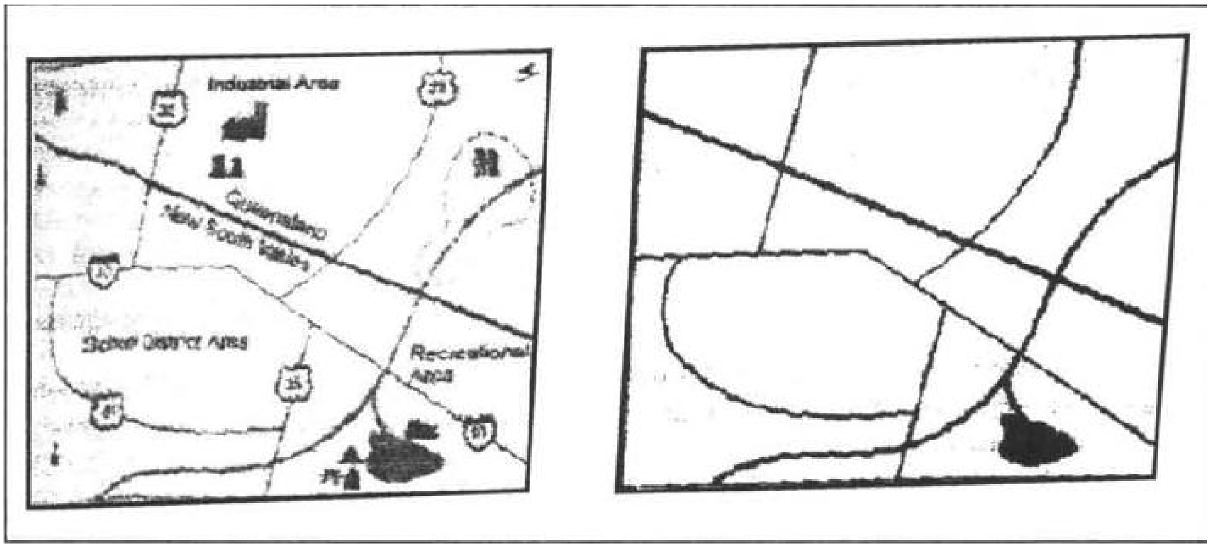


Fig 5.4 Scanned output map

5.4 ATTRIBUTE DATA ANALYSIS

Attribute data tells the characteristics of different objects / features on the earth surface. These are descriptions, measurements or classification of geographic features. Attribute data can be both qualitative (like land use type, soil type, name of the city/river etc.) and quantitative (like elevation, temperature, pressure of a particular place, crop yield per acre etc.). So, the attribute can be both numeric and textual. The examples of attribute data of different spatial features like point (well), line (river), area (village) are shown in box 1. The attribute data are generally in tabular form.

Different Types Of Spatial Data Analysis Can Be Performed By Gis, Viz. Performing Queries, Proximity Analysis, Network Analysis, Overlay Operations, and Model Building Etc. Since Gis Stores Both Spatial And Non Spatial Data And Links Them Together, It Can ***Perform Different Types Of Queries***.

For Example By Joining The Spatial Data And Its Attributes. And Then By Performing Queries, One Can See On Map, The Water Of Which Tube Wells Having Chlorine Content More Than 200 Mg/Litre. Likewise One Can See On Map). The Roads Constructed Before 1980 Which Need To Be Repaired. In The Same Way, Which Area Of A Given Forest Having More Than 60 Per Cent Tree Density, Can Be Shown On The Map (By Joining Map Of The Forest Shown In Figure 6 And Its Attribute Table Given In Table 3)

Proximity Analysis

Can Be Done Through Buffering, I.E. Identifying A Zone Of Interest Around A Point, Line Or Polygon. For Example, 10 M. Around On Tube Well Can Be Marked For Planting Flower Plants; Or 50 M. Along National Highways (Both Sides) Can Be Buffered For Planting Trees. A Specified Distance Around The Forest Can Be Buffered As No Habitation Zone.

Network Analysis

Is Another Important Analysis Done Through Gis. For Example Optimum Bus Routing Can Be Determined By Examining All The Field Or Attribute Data (Given In Table 2) Linked To Road Map / Spatial Data.

Overlay Operation

Can Be Done Through Gis By Overlaying / Integrating A Number Of Thematic Maps. Overlay Operation Allows Creation Of A New Layer Of Spatial Data By Integrating The Data From Different Layers. For Example, A Particular Land Use Class Having Saline Soils, Slope Less Than 20%, Drainage Density Less Than 10 M. Per Squre Km. Can Be Created From Four Different Thematic Maps, Viz. Land Use Map, Soil Map, Topographic Map And Water Resource Map.

Model Building Capability Of Gis Is Very Helpful For Decision Makers. It Is Usually Referred To As ‘What If’ Analysis. For Example, If A Certain Amount Of Water Is Released From A Dam, How Much Area Would Be Inundated?

5.5 INTEGERATED DATA ANALYSIS

GIS model is the integrated data model which is more closely integrated with the database management system than in the hybrid system. The integrated data model approach is also described as the spatial data base management system approach, with the GIS serving as the query processor sitting on top of the database itself. The integrated data model has a number of implications in terms of the special characteristics of spatial data. From the data base viewpoint, it is possible to store both the coordinates and the topological information required to characterise digital cartographic elements using a design based on Codd's Normal Forms. (x, y) coordinate pairs for individual vertices along line segments are stored as different rows in a data base table. To achieve satisfactory retrieval performance it has been found necessary to store coordinate strings in long or 'bulk data' columns in tables. Handling of large spatial databases is the need to convert 2-D coordinate information into 1-D spatial keys that can be stored as data base table columns. These can then be indexed in the normal way and used for fast retrieval of map elements contained within or overlapping a specified geographical search area.

There are two ways of storing coordinate information as relational tables. The first records individual (x, y) coordinate pairs and polygon terminator and vertices as individual atomic elements or a row in a database. It is very difficult to search any element because each element must be recomposed from its atomic format to grate whole polygons or groups of polygons. The integrated GIS with which it can be understood how a single database can be configured to certain separate files for entities and attributes.GIS purpose are based on entities, attributes, and the relationship between entities and attributes with respect to the locations, temporal changes and both location and time. In the following sections, an attempt is made to provide a preliminary study for creating object based data models on the basis of entity-attribute relationships, location based representations of spatio-temporal data, and time based representations of spatio-temporal data and a combined approach of representing spatio-temporal data.

5.6 MODELING IN GIS HIGHWAY ALINGMENT STUDIES

Vector GIS displays the locations or all objects stored using points and arcs.Attributes and entity types can be displayed by varying colors, line patterns and point symbols (Fig) . Using vector GIS, one may display only a subset of the data. For example, one may select all political boundaries and highways, but only areas that had urban land uses.

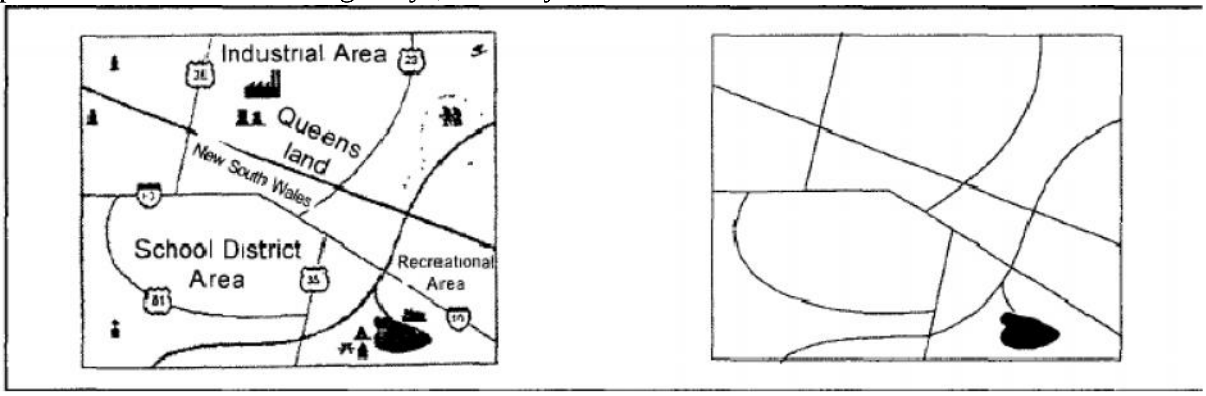
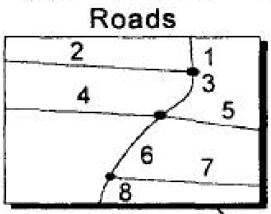
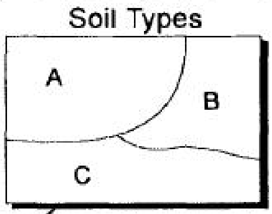


Fig 5.5 Boundaries and highways

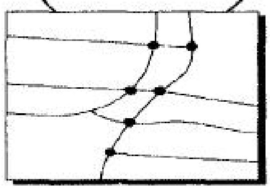
Relational query is an important concept in vector overlay analysis. Differentsystems use different ways of formulating queries. Structured Query language (SQl) is used by many systems. It provides a "standard" way in querying spatial data bases. Using relational queries, the user can select objects interested in producing map output using colours, symbols, text annotations and so on. Reclassify, dissolve, and merge operations are used frequently in working with area objects. They are used to aggregate areas based on attributes. Consider a soil map in Fig. We wish to produce a map of major soil types from a layer that has polygons based on much more finely defined classification scheme. To do this, we process the data using three steps: (i) Reclassify areas by a single attribute or some combination; for instance reclassify soil areas by soil type only (ii) Dissolve boundaries

Lines are broken at each area object boundary to form new line segments andnew attributes created for each output line specifying the area it belongs to Fig.





ID	Highway
1	35
2	22
3	35
4	60
5	60
6	35
7	82
8	35



ID	Soil Type
A	Black
B	Brown
C	Red

ID	Original	Highway	Soil Type
1	2	22	Black
2	2	22	Brown
3	1	35	Brown
4	3	35	Brown
5	4	60	Black
6	4	60	Brown
7	5	60	Brown
8	6	60	Brown
9	6	35	Red
10	7	82	Red
11	8	35	Red

A triangulated irregular network (TIN) is a digital data structure used in a geographic information system (GIS) for the representation of a surface. A TIN is a vector based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three dimensional coordinates (x,y, and z) that are arranged in a network of nonoverlapping triangles. TINs are often derived from the elevation data of a rasterized digital elevation model (DEM). An advantage of using a TIN over a DEM in mapping and analysis is that the points of a TIN are distributed variably based on an algorithm that determines which points are most necessary to an accurate representation of the terrain. Data input is therefore flexible and fewer points need to be stored than in a DEM with regularly distributed points. While a TIN may be less suited than a DEM raster for certain kinds of GIS applications, such as analysis of a surface's slope and aspect, TINs have the advantage of being able to portray terrain in three dimensions.

A TIN comprises a triangular network of vertices, known as mass points, with associated coordinates in three dimensions connected by edges to form a triangular tessellation. Three-dimensional visualizations are readily created by rendering of the triangular facets. In regions where there is little variation in surface height, the points may be widely spaced whereas in areas of more intense variation in height the point density is increased.

Characteristics

Contours should always point downridge along ridges Adjacent contours should always be sequential or equivalent

Contours should never split into two

Contours should never cross or loop

Contours should never spiral

Contours should never stop in the middle of a map

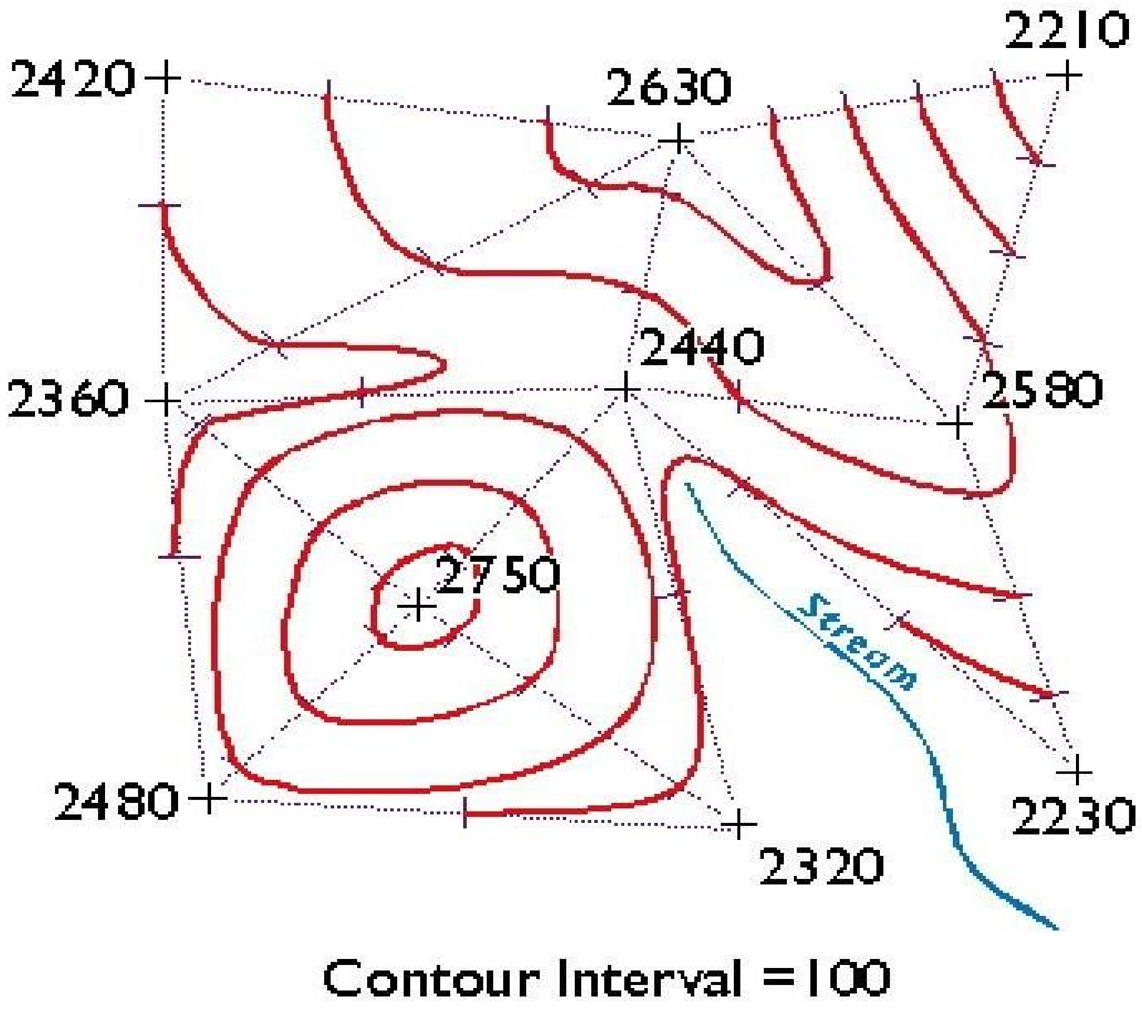


Fig 5.6 Contour Map

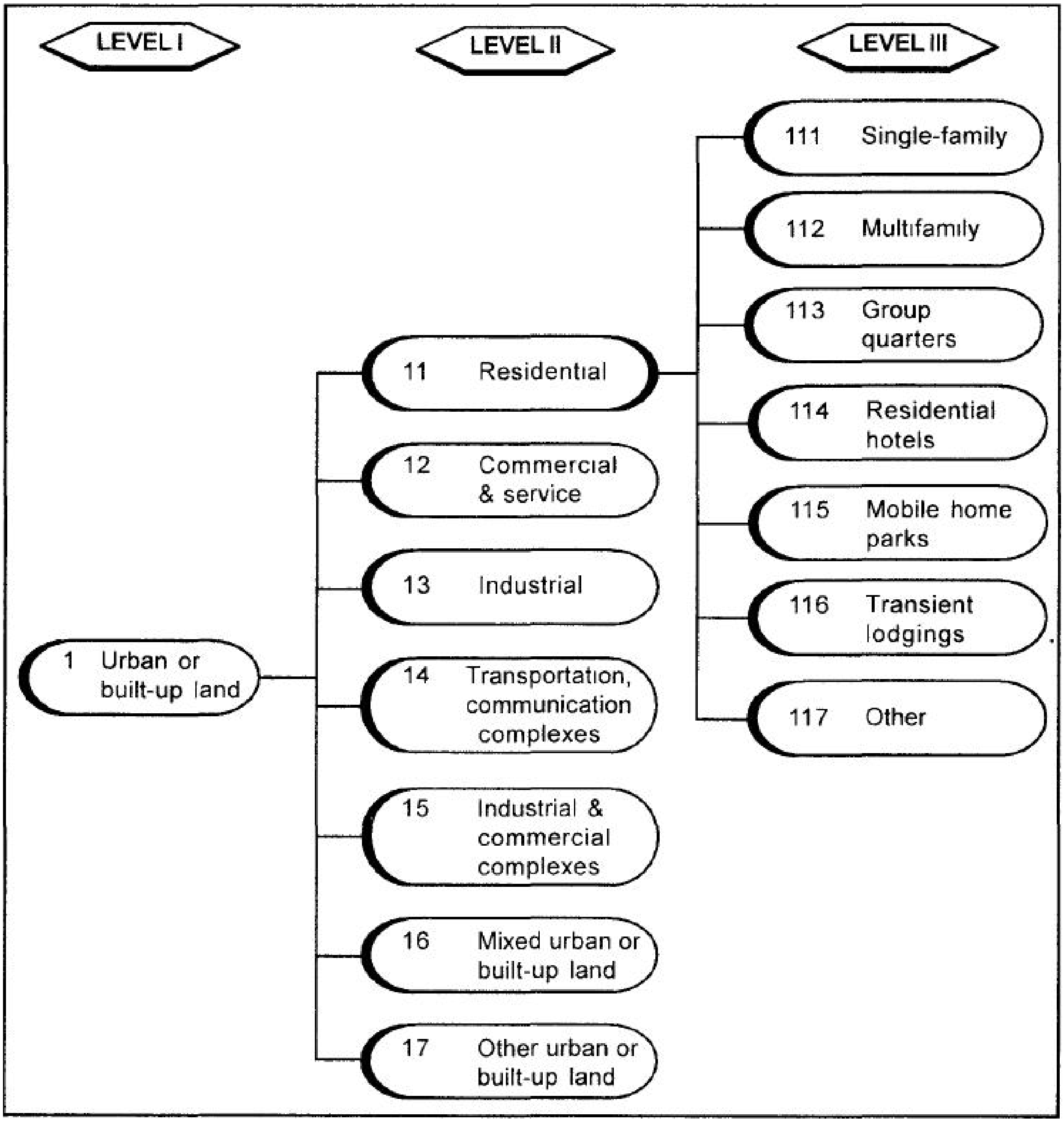
A streamlined approach is developed for Land Information System to LIS thatincorporates key data into a land registration structure, subsequently transferring them into a fully automated information system. Under this approach, a land parcel is not stored as a polygon or area in the LIS and hence is not used as the base framework for the related database. Instead, a single point feature representing each property is used as the identifier and geographic locator and are usually termed as, "lots by dots." This is the critical difference from the polygon-based approach which attempts to reconcile geometry and compile all land parcels together into a contiguous map of polygons. This is practically impossible to achieve even in the United States since individual surveys of land parcels or 'lots' are often, not entirely accurate and do not actually reconcile with one another.

This point-based property database can be developed from hardcopy very highresolution satellite imagery or aerial photographs, or through ground-based collection using Global Positioning System (GPS) techniques. As the field person collects the geographic (point) position of each land parcel the property identifier number as well as physical characteristics of the land, such as, land cover, soil condition, and number of structures can also be logged. This effectively allows an LIS database to be built in the field during survey. Additional complementary data can also be integrated into the LIS, such as, scanned property documents.

5.7 LAND INFORMATION SYSTEM

The land use/land cover system adopted by almost all concerned organisationsand scientists, engineers and remote sensing community who are involved in mapping of earth surface features, is a system derived from the United States Geological Survey (USGS) land use/land cover classification system. This system was designed on the basis of the following criteria (Lillesand and Kiefer 1999) : (i) the minimum level of interpretation accuracy using remotely sensed data should be at least 85 percent, (ii) the accuracy of interpretation for the several categories should be about equal, (iii) repeatable results should be obtainable from one interpreter to another and from one time of sensing to another, (iv) the classification system should be applicable over extensive areas, (v) the categorization should permit land use to be inferred from the land cover types, (vi) the classification system should be suitable for u'se with remote sensor data obtained at different times of the year, (vii) categories should be divisible into more detailed subcategories that can be obtained from large-scale imagery or ground surveys, (viii) aggregation of categories must be possible, (ix) comparison with future land use and land cover data should be possible, and (x) multiple uses of land should be recognized when possible.

The basic USGS LU/LC classification system for use with remote sensor data isshown in Table 14.1. On the basis of this system a multi-level system has been devised because different degrees of detail can be obtained from aerial and space images, which depend upon the resolution. Fig. 14.1 illustrates a sample aggregation of classifications for levels III, II and I. One more level that is level IV is also devised for local users. In principle, levels IV and III are designed for local level or very large scale mapping whereas levels II and I are meant for small scale mapping.
Table 14.2 lists representative interpretation formats for various land use/land cover classification levels.


LEVEL I
LEVEL II
LEVEL III
1 Urban or built-up land
11 Residential
12 Commercial & service
13 Industrial
14 Transportation, communication complexes
15 Industrial & commercial complexes
16 Mixed urban or built-up land
17 Other urban or built-up land
111 Single-family
112 Multifamily
113 Group quarters
114 Residential hotels
115 Mobile home parks
116 Transient lodgings
117 Other

USGS Land Use/Land Cover Classification System for use with Remote Sensor Data

Level II	Level II
1. Urban or built-up land	11 Residential 12 Commercial and service 13 Industrial 14 Transportation, communications, and utilities 15 Industrial and commercial complexes 16 Mixed urban or built-up land 17 Other urban or built-up land
2. Agriculture land	21 Cropland and pasture 22 Orchards, groves, vineyards, nurseries, and ornamental horticultural areas 23 Other agricultural land
3. Rangeland	31 Herbaceous rangeland 32 Shrub and brush rangeland 33 Mixed rangeland
4. Forest land	41 Deciduous forest land 42 Evergreen forest land 43 Mixed forest land
5. Water	51 Streams and canals 52 Lakes 53 Reservoirs 54 Bays and estuaries
6. Wetland	61 Forested wetland 62 Nonforested wetland
7. Barren land	71 Dry salt flats 72 Beaches 73 Sandy areas other than beaches 74 Bare exposed rock 75 Strip mines, quarries, and gravel pits 76 Transitional areas 77 Mixed barren land
8. Tundra	81 Scrub and bush tundra 82 Herbaceous tundra 83 Bare ground tundra 84 Wet tundra 85 Mixed tundra
9. Perennial snow or ice	91 Perennial snowfields 92 Glaciers

National Remote Sensing Agency (NRSA), Government of India, has devised ageneralised land uselland cover classification system with respect to the Indian conditions based on the various categories of Earth surface features, resolution of available satellite data, capabilities of sensors, and present and future applications. Table shows the general legend adapted for land use/land cover categories. This system is used for the development of land use/land cover map for the project area, namely, MCH area of Hyderabad.

402

Level - I	Level - II	Level - III	Level - IV	Code
1. Built-up-Land	1.1 Town/Cities Villages	1.1.1 Residential		01
		1.1.2 Industrial		
			1.1.2.1 Salt Pans	02
			1.1.2.2 Others	03
2. Agricultural Land	2.1 Crop Land	2.1.1 Kharif		04
		2.1.2 Rabi		05
		2.1.3 Kharif+Rabi		06
		2.1.4 Summer		07
		2.1.5 Kharif+Summer		08
		2.1.6 Rabi + Summer		09
		2.1.7 Kharif + Rabi + Summer		10
	2.2 Fallows			11
	2.3 Plantations	2.3.1 Agro Horticulture		12
		2.3.2 Horticulture		13
3. Forest	3.1 Evergreen/ Semi Evergreen	3.1.1 Dense		14
		3.1.2 Open		15
		3.1.3 Scrub Forest		16
		3.1.4 Forest Blanks		20
	3.2 Deciduous	3.2.1 Dense/Closed		18
		3.2.2 Open		19
		3.2.3 Forest		20
		3.2.4 Forest Blanks		21
	3.3 Forest Plantations			22
	3.4 Mangrove	3.4.1 Dense		23
		3.4.2 Sparse		24
	3.5 Evergreen/ Semi-Evergreen (Unnotified)	3.5.1 Dense (Unnotified)		25
		3.5.2 Open (Unnotified)		26
		3.5.3 Forest Blanks (Unnotified)		27

Level - I	Level - II	Level - III	Level - IV	Code
	3.6 Deciduous (Unnotified)	3.6.1 Dense (Unnotified)		28
		3.6.2 Open (Unnotified)		29
		3.6.3 Forest Blanks (Unnotified)		30
	3.7 Forest Plantation (Unnotified)			31
	3.8 Mangrove (Unnotified)	3.8.1 Dense (Unnotified)		32
		3.8.2 Sparse (Unnotified)		33
4. Wastelands	4.1 Salt Affected Land			34
	4.2 Gullied/Ravinous Land			35
	4.3 Land with Scrub			36
	4.4 Land without Scrub			37
	4.5 Sandy Area (Coastal/Desertic)			38
	4.6 Mining/Industrial Wasteland			39
	4.7 Barren Rocky/ Stony waste/Sheet Rock Area			40
5. Water Bodies	5.1 River			41
	5.2 Canals			42
	5.3 Lake/Pond			43
	5.4 Reservoir			44
	5.5 Tank			45
	5.6 Cooling Pond/ Cooling Reservoir			46
	5.7 Abandoned Quarries With water			47

Level - I	Level - II	Level - III	Level - IV	Code
	5.8 Bay	5.8.1 Back waters		48
		5.8.2 Estuary/Kayal		49
		5.8.3 Creek		50
		5.8.4 Lagoon		51
	5.9 Cut-off Meander			52
6. Wetlands	6.1 Inland/ Wetlands	6.1.1 Water Logged		53
		6.1.2 Marshy/Swampy		54
		6.1.3 Oxbow Lake		55
	6.2 Coastal	6.2.1 Marsh Veg.		56
		6.2.2 Algae		57
		6.2.3 Mud Flats	6.2.3.1 High Tidal Flats	58
			6.2.3.2 Inter Tidal	59
			6.2.3.3 Sub-Tidal	60
			6.2.3.4 High Tidal With Salt Encrustations	61
		6.2.4 Sand	6.2.4.1 Spit	62
			6.2.4.2 Bar	63
			6.2.4.3 Shoals	64
			6.2.4.4 Beach Ridges	65
			6.2.4.5 Plantations On Sand	66
		6.2.6 Rocky Coast		67
7. Grass Land/ Grazing Land	7.1 Dense			68
	7.2 Degraded			69

UNIT I

EMRAND ITSINTERACTIONWITH ATMOPHEREAND EARTH MATERIAL

1.What is Remote Sensing?

Remote sensing is the science and art of obtaining information about object, area, or phenomena through the analysis of data acquired by a device that is not in contact with the object, area, or phenomena under investigation.

2.What are all the applications of remote sensing?

In many respects, remote sensing can be thought of as a reading process. Using various sensors, we remotely collect data that may be analyzed to obtain information about the objects, areas,or phenomena beinginvestigated. The remotely collected data can be of many forms, including variations in force distributions, acoustic wave distributions, or electromagnetic energy distributions.

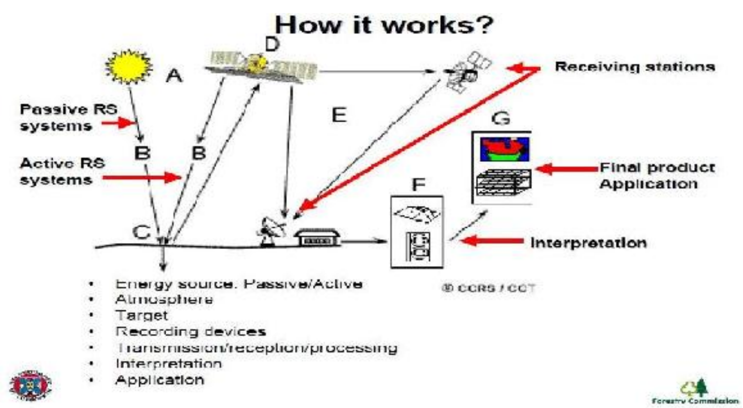
3.Write the physics of remote sensing ?

Visible light is only one of many forms of electromagnetic energy. Radio waves, heat, ultraviolet rays, and X-rays are other familiar forms. All this energy is inherently similar and radiates in accordance with basic wave theory. This theory describes electromagnetic energy as traveling in harmonic, sinusoidal fashion at the “velocity of light” c. The distance from one wave peak to the next is the wave length ψ, and the number of peaks passing a fixed point in space per unit time is the wave frequency V.

From basic physics, wave obey the general equation

$$C = v\ y$$

4.What are the Components of Remote Sensing ?



5.What is Electromagnetic radiation?

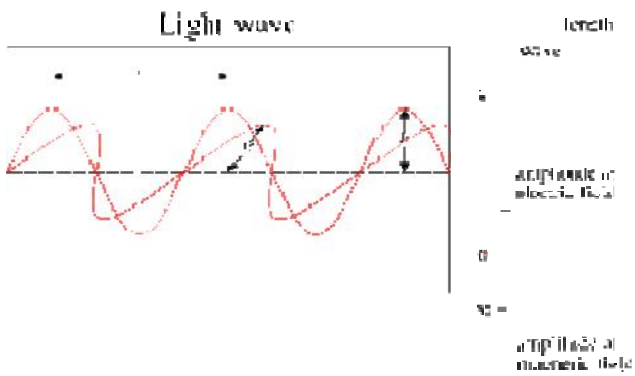
Electromagnetic (EM) radiation is a self-propagating wave in space or through matter. EM radiation has an electric and magnetic field component which oscillate in phase perpendicular to each other and to the direction of energy propagation.

6.Write the type of Electromagnetic radiation?

Electromagnetic radiation is classified into types according to the frequency of the wave, these types include (in order of increasing frequency): radio waves, microwaves, terahertz radiation, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays.

7.Draw the quantum theory interaction?

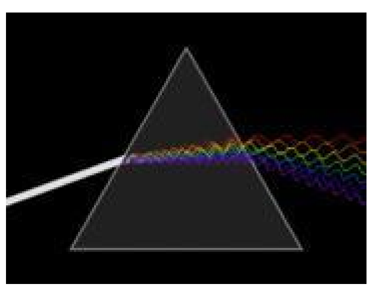
A quantum theory of the interaction between electromagnetic radiation and matter such as electrons is described by the theory of quantum electrodynamics.



8.Write about refraction?

In refraction, a wave crossing from one medium to another of different density alters its speed and direction upon entering the new medium. The ratio of the refractive indices of the media determines the degree of refraction, and is summarized by Snell's law. Light disperses into a visible spectrum as light is shone through a prism because of refraction.

9.Draw the Wave model?



10.Write Planck's equation?

The frequency of the wave is proportional to the magnitude of the particle's energy. Moreover, because photons are emitted and absorbed by charged particles, they act as transporters of energy. The energy per photon can be calculated by Planck's equation:

where E is the energy, h is Planck's constant, and f is frequency.

11.What is Black body ?

By definition a *black body* is a material that absorbs all the radiant energy that strikes it. A black body also radiates the maximum amount of energy, which is dependent on the kinetic temperature.

12.Write Stefan Boltzman law?

According to the Stefan-Boltzman law the radiant flux of a black body, Fb, at a kinetic temperature, Tkin, is Fb = s* Tkin
4 where s is the Stefan- Boltzman constant, 5.67*10-12 W*cm-2*°K-
4.

13.What is emissivity?

Emissivity is a measure of the ability of a material to both radiate and absorb energy. Materials with a high emissivity absorb and radiate large proportions of incident and kinetic energy, respectively (and vice-versa).

14.Write Wein's Displacement law?

For an object at a constant temperature the radiant power peak refers to the wavelength at which the maximum amount of energy is radiated, which is expressed as lmax. The sun, with a surface temperature of almost 6000°K, has its peak at 0.48mm (wavelength of yellow). The average surface temperature of the earth is 290°K (17°C), which is also called the *ambient temperature*; the peak concentration of energy emitted from the earth is at 9.7mm.This shift to longer wavelengths with decreasing temperature is described by Wien's displacement law, which states:

lmax = 2,897mm°K
/Trad°K

15.Write Planck's Law?

The primary law governing blackbody radiation is the *Planck Radiation Law*, which governs the intensity of radiation emitted by unit surface area into a fixed direction (solid angle) from the blackbody as a function of wavelength for a fixed temperature. The Planck Law can be expressed through the following equation.

16.What is Scattering?

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere. There are three (3) types of scattering which take place.

17.What are the types of scattering?

(i) Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation.

(ii) Mie scattering

It occurs when the particles are just about the same size as the wavelength of the radiation.

(iii) Non Selective Scattering

The final scattering mechanism of importance is called **nonselective scattering**.
This occurs when the particles are much larger than the wavelength of the radiation.

18.What is Atmospheric Windows?

The areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called **atmospheric windows**.

PART B

1. Discuss on spectral signature and its rule in identifying objects with suitable diagrams.
2. Explain the principle of working of remote sensing?
3. With a suitable diagram explain the Electromagnetic Spectrums and its characteristics used in remote sensing?
4. Explain on the different types of interactions of EMR with atmosphere?

UNIT II

PLATFORMS AND SENSORS

PART A

1.What is passive sensors?

Passive sensors can only be used to detect energy when the naturally occurring energy is available. For all reflected energy, this can only take place during the time when the sun is illuminating the Earth. There is no reflected energy available from the sun at night. Energy that is naturally emitted (such as thermal infrared) can be detected day or night, as long as the amount of energy is large enough to be recorded.

2.What is Active sensors?

On the other hand, provide their own energy source for illumination. The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor.

3.Write the advantages of active sensors?

Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season. Active sensors can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves, or to better control the way a target is illuminated. However, active systems require the generation of a fairly large amount of energy to adequately illuminate targets. Some examples of active sensors are a laser fluorosensor and a synthetic aperture radar (SAR).

4. What are the types of Platforms?

The vehicle or carrier for remote sensor is borne is called the Platform.” The typical platforms are satellite and aircraft, but they can also include radio controlled airplanes, balloons, pigeons, and kites for low altitude remote sensing, as well as ladder and cherry pickers for ground investigation.

5.Differentiate Geostationary orbit and Polar sun synchronous orbit.

Geostationary orbit
High altitude (36,000km)
Remains in same position above the Earth
Used by meteorological and communications satellites

Sees Earth disk (between third and quarter of Earths surface) High temporal frequency (c.30 mins typical)

Polar sun synchronous orbit

Low altitude (200-1000km) Goes close to poles

Higher spatial resolution than geostationary

Lower temporal resolution than geostationary

6. What is Resolution?

In general resolution is defined as the ability of an entire remote-sensing system, including lens antennae, display, exposure, processing, and other factors, to render a sharply defined image.It is the resolving power of the sensor to detect the smallest meaningful elemental area in different spectral bands in s defined gray level at a regular interval.

7.What are the elements of resolution?

The four elements of resolutions are Spatial, Spectral, Radiometric and Temporal.

8. Write short notes about Spatial resolution.

It is the minimum elemental area the sensor can detect or measure. The resolution element is called pixel (picture element).

Example: IRS LISS 1-72.5m; LISS II-36.25m

Land sat MSS-80m; Land sat TM-30m

SPOT MSS HRV-120m; SPOT MSS HRV II-10m

9. Write short notes about Spectral resolution.

It refers to the sensing and recording power of the sensor in different bands of EMR. The sensors can observe an object separately in different bands or colors.

Examples: IRS-4 bands; Land sat MSS-4 bands; Land sat MSS TM-7 bands SPOT-4 bands

It is the ability if the sensor to distinguish the finer variation of the reflected radiation from different objects.

It is the smallest amount of energy that can be detected by sensor and differentiate the same in a defined scale. It is recorded in digital number (DN) for different bands of the satellite. The radiometric value of the pixel is the average of the values coming from every part of the pixel.

Example: IRS-128 gray level; Land sat MSS-64; Land sat TM-256; SPOT-256(it is to be noted that ‘0’is also a value in the gray scale).

11. Write short notes on Temporal resolution.

It is the time interval between two successive surveys of a particular place of the earth by the sensor or satellite.

Examples: IRS-22days; Land sat 16/18days; SPOT-16days.

12. Write the types of Microwave Sensors?

Active microwave sensors are generally divided into two distinct categories:

imaging and non-imaging. The most common form of imaging active microwave sensors is RADAR.

13.What is RADAR?

RADAR is an acronym for **RA**dio **D**etection **A**nd **R**anging, which essentially characterizes the function and operation of a radar sensor. The sensor transmits a microwave (radio) signal towards the target and detects the backscattered portion of the signal.

14. What are the types of DATA products?

The data for all the sensors of IRS -1C/1D are supplied on digital media like a) Computer copatible tapes (CCTs)
b) Cartridge tapes c) Floppies
d) CD-ROM products

PART B

1.What is resolution of a sensor? Describe all sensor resolutions.
2.Write short notes on the Indian remote sensing programme.
3.What is the role of a scanner in remote sensing and describe the different types of scanners used in remote sensing.
4.Discuss the thermal infrared in remote sensing?
5. Give details and examples about platforms and sensors.
6. What are the two type of sensors and discuss detail?

UNIT III

IMAGE INTERPRETATION AND ANALYSIS

PART A

1.What is image interpretation?

Image interpretation is defined as the extraction of qualitative and quantitative information in the form of a map, about the shape, location, structure, function, quality, condition, relationship of and between objects, etc. by using human knowledge or experience.

2. What are all the Types of image interpretation?

Photo interpretation photographic interpretation and image interpretation are the terms used to interpret the Visual Image Interpretation.

3. What is Visual Image interpretation?

Visual Image interpretation is the act of examining photographs/images for the purpose of identifying objects and judging their significance"

4. What is Photo interpretation?

Photo interpretation is defined as the process of identifying objects or conditions in aerial photographs and determining their meaning or significance.

4.What is image reading?

Image reading is an elemental form of image interpretation. It corresponds to simple identification of objects using such elements as shape, size, pattern, tone, texture, color, shadow and other associated relationships. Image reading is usually implemented with interpretation keys with respect to each object .

5.What is image measurement?

Image measurement is 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.

6. What is image analysis?

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

7. What is thematic map?

Extracted information will be finally represented in a map form called an interpretation *map or a thematic map.*

8. What are the Image interpretation elements ?

The eight elements of image interpretation are shape, size, tone, shadows, texture, site, pattern and association.

9. What is Digital Image Processing?

Digital Image Processing is a collection of techniques for the manipulation of digital images by computers. The raw data received from the imaging sensors on the satellite platforms contains flaws and deficiencies. To overcome these flaws and deficiencies in order to get the originality of the data, it needs to undergo several steps of processing. This will vary from image to image depending on the type of image format, initial condition of the image and the information of interest and the composition of the image scene.

10. What are the general steps of image processing? The three steps of image processing are ,

- Pre-processing
- Display and enhancement
- Information extraction

11.Write about pre processing?

In the preprocessing ,prepare data for subsequent analysis that attempts to correct or compensate for systematic errors.

12. What is Image Enhancement?

The *o*perations are carried out to improve the interpretability of the image by increasing apparent contrast among various features in the scene. The enhancement techniques depend upon two factors mainly l The digital data (i.e. with spectral bands and resolution)

14. Write the objectives of interpretation?

The objectives of interpretation as an image enhancement technique often drastically alters the original numeric data, it is normally used only for visual (manual) interpretation and not for further numeric analysis. Common enhancements include image reduction, image rectification, image magnification, transect extraction, contrast adjustments, band ratioing, spatial filtering, Fourier transformations, principal component analysis and texture transformation.

15.What is digital image?

Digital Image is the matrix of “Digital Numbers”. A digital image is composed of thousands of pixels. Each pixel represents the brightness of small region on the earth surface.Digital Image processing involves the manipulation and interpretation of digital image with the aid of computer.

16.What is filtering?

Filtering means the smoothening of an image using different Masks or Kernels.\

17.What is spatial filtering?

“ Spatial Filtering can be described as selectively emphasizing or suppressing information at different spatial scales over an image. “

Spatial operation consists in changing the values of each pixels according to the values of the pixels in the neighborhoods.

18.What is convolution?

A convolution is an integral which expresses the amount of overlap of one function *g* as it is shifted over another function *f*. “

PART B

1.Write a detailed description on the elements of visual interpretation quoting suitalble examples for each.

2.Give a detailed description on the how the flaws and deficiency in remote sensing data can be removed.

3.Describe the different digital image processing techniques used.

4.Give a deatailed description on image classification and analysis of a remotely sensed data.What is the use of classifying image.

UNIT IV
GEOGRAPHIC INFORMATION SYSTEM

1.What is map?

A map is usually considered to be a drawing to scale of the whole or a part of the surface of the earth on a plane surface; it is a manually or mechanically drawn picture of the earth showing the location and distribution of various natural and cultural phenomena.A map is a symbolic representation of an area.

2.Write the two types of maps?

The two maps are topographical and thematic maps.

3.Write about topographical map?

It is a reference tool, showing the outlines of selected natural and man-made features of the Earth

– often acts as a frame for other information

"Topography" refers to the shape of the surface, represented by contours and/or shading, but topographic maps also show roads and other prominent features.

4.Write about thematic map?

It is a tool to communicate geographical themes such as, the distribution of population & densities, climatic variables and land use etc.

5.What are the thematic maps in GIS?

a)choropleth map
b) area class map
c) isopleth map

6.What are the characteristics of map?

- maps are often stylized, generalized or abstracted, requiring careful interpretation
- usually out of date

- show only a static situation - one slice in time
- often highly elegant/artistic
- easy to use to answer certain types of questions:
  - how do I get there from here?
  - what is at this point?
- difficult or time-consuming to answer other types:
  - what is the area of this lake?
  - what places can I see from this TV tower?
  - what does that thematic map show at the point I'm interested in on this topographic map?

7.Write the necessity of map projection?

Projection is necessary one because spatial entities locate in two dimensions. The method by which the "world is laid flat" is use to help projection. Doing the process introduce error into spatial data. Spatial data character varies depending on the projection method chosen. Shape and distance are distorted the accuracy world is spherical shape visualize the two dimension in flat surface is difficult.

8.Write the types of map projection?

1.Cylindrical projection 2. Azimuthal projection
3. Conical projection

9.Write few lines about cylindrical projection?

Countries near the equator in true relative portion
Distance increases between countries located towards top and bottom of mage. The view of the poles is very distorted
Area for the most part is preserved

10.Write few lines about conical projection?

Area is distorted.
Distance is very distorted towards the bottom of the image. Scale for the most part is preserved

11.Write few lines about azimuthal projection?

Only a part of the earth surface is visible.
The view will be of half the globe or less. Distortion will occur at all four edges. Distance for the more part is preserved.

12.What is referencing system?

Referencing system is used to locate a feature on the earth's surface or a two dimension representation of this surface such as a map.

13.What are the methods of spatial referencing systems?

Several methods of spatial referencing exist all of which can be grouped into three categories.

Geographical co-ordinate
system Rectangular co-ordinate
system Non-co-ordinate system

14. What is Geographic Co-Ordinate System?

This is a one of true co-ordinate system .the location of any point on the earth surface can be defined by a reference using latitude and longitude.

15.What is QTM?

The quaternary triangular mesh refrenshing system tries to deal with irregularities in the earth surface.

16.What is GIS?

It's a computer based information system primarily aims in collecting, classifying, crosschecking, manipulating, interpreting, retrieving and displaying data which are spatially referred to the earth in an appealing way.

17.What are the components of GIS?

i) The Computer System (Hardware and Operating System)
ii) The
Software iii)
Spatial Data
iv) Data Management and analysis
procedures v) The People to operate the GIS

18.What are the GIS softwares used?

Standard GIS Softwares

- ARCGIS
- ARCVIEW
- ARCINFO
- MAPINFO
- ERDAS
- ENVI
- AUTOCADMAP
- IDRISI

PART B

1.What is map projection and explain the differentiate types of map projections with their characteristics.

2.Explain in detail on the different types of data utilized in GIS technology.

3.Explain the different classification of maps.

4.Explain DBMS ,with emphasis on the differentiate types of DBMS used in GIS functioning.

UNIT V

DATA - ENTRY ,STORAGE AND ANALYSIS

1.What is Data model?

Data Models: Vector and Raster

Spatial data in GIS has two primary data formats: raster and vector.

Raster uses a grid cell structure, whereas vector is more like a drawn map.

Raster and Vector Data

Vector format has points, lines, polygons that appear normal, much like a map.

Raster format generalizes the scene into a grid of cells, each with a code to indicate the feature being depicted. The cell is the minimum mapping unit.

Raster has generalized reality: all of the features in the cell area are reduced to a single cell identity.

2.What is raster data?

Raster is a method for the storage, processing and display of spatial data.

Each area is divided into rows and columns, which form a regular grid structure. Each cell must be rectangular in shape, but not necessarily square.

Each cell within this matrix contains location co-ordinates as well as an attribute value. The origin of rows and column is at the upper left corner of the grid. Rows function as the "y"coordinate and column as"x"coordinate in a two dimensional system. A cell is defined by its location in terms of rows and columns.

3.What is vector data?

- Vector data uses two dimensional Cartesian coordinates to store the shape of spatial entity. Vector based features are treated as discrete geometric objects over the space.
- In the vector data base point is the basic building block from which all the spatial entities are constructed.
- The vector spatial entity ,the point is represented by a single x,y coordinate pair. Line and area entities are constructed by a series of points into chains and

4. What is Raster?

The raster cell's value or code represents all of the features within the grid, it does not maintain true size, shape, or location for individual features. Even where "nothing" exists (no data), the cells must be coded.

5. What is Vector?

vectors are data elements describing position and direction. In GIS, vector is the map-like drawing of features, without the generalizing effect of a raster grid. Therefore, shape is better retained. Vector is much more spatially accurate than the raster format.

6.What is raster coding?

In the data entry process, maps can be digitized or scanned at a selected cell size and each cell assigned a code or value.

The cell size can be adjusted according to the grid structure or by ground units, also termed resolution.

There are three basic and one advanced scheme for assigning cell codes.

Presence/Absence: is the most basic method and to record a feature if some of it occurs in the cell space.

7. What is Cell Center?

The cell center involves reading only the center of the cell and assigning the code accordingly. Not good for points or lines.

8.What is Dominant Area?

To assign the cell code to the feature with the largest (dominant) share of the cell. This is suitable primarily for polygons.

9.What is Percent Coverage?

A more advanced method. To separate each feature for coding into individual themes and then assign values that show its percent cover in each cell.

10.Different methods of data input?

Key board entry

Digitizing

Manual digitizing

Automatic digitizing

Scanning
Automatic line follower
Electronic data transfer

11. What is digitizing?

The most common method employed in encoding data from a paper map.

Manual digitizing
Automatic digitizing
Scanning
Automatic line follower

12.Write the errors in digitizing?

Scale and resolution of the source/base map.
Quality of the equipment and the software used.
Incorrect registration.
A shaky hand.
Line thickness.
Overshoot.
Under shoot.
Spike.
Displacement.
Polygonal knot.
Psychological errors.

13.What is scanning?

piece of hard ware for converting an analogue source of document into digital raster format (a light sensitive device).
Most commonly used method.
When raster data are there to be encoded scanning is the most appropriate option.
There are three different types of scanners available in usage :-
Flat-bed scanners (a PC peripheral). Rotating drum scanners.
Large format feed scanners

14.Write the important components of scanner?

A light source.
A back ground.
A lens.

15.Write the practical problems in scanning?

Possibility of optical distortion associated with the usage of flat bed scanners.
Automatic scanning of unwanted information.
Selection of appropriate scanning tolerance to ensure important data are encoded, and background data ignored.
The format of files produced and the input of data into G.I.S. software.
The amount of editing required to produce data suitable for analysis.

PART B

1.What is data model ?Enumerate different types of GIS data.

2.Write short notes on:

(i) Overlaying
(ii) Buffering and GIS

3.What are the possible techniques best adopted for better storage of raster data that would avoid repetition of characters.
4.Explain on the different methods of data input in GIS.

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Question Paper Code : 11200

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2011

Sixth Semester

Civil Engineering

CE 2024 — REMOTE SENSING TECHNIQUES AND GIS

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions

PART A — (10 × 2 = 20 marks)

1. What are the components of Remote Sensing System?
2. Explain in briefly Spectral Reflectance of Water bodies.
3. Describe balloons and aircraft under airborne platforms.
4. Write the importance of Earth Resources Satellites.
5. What are the types of Data products?
6. Define image Rectification and Restoration.
7. Explain in detail about different types of Map Projection.
8. What are the important functions of Data base management system?
9. Write the classification of data input to a Geographic Information System.
10. Definition of Geometric Correction and Radiometric Correction.

PART—B (5 × 16 = 80 marks)

11. (a) What is mean by Electromagnetic Spectrum and Explain in detail for Energy Source and its characteristics with neat sketch?

Or

(b) Explain in detail with neat sketches for Atmospheric interactions with Electro Magnetic Radiation.

12. (a) What are the different types of platform and explain in detail with give examples?

Or

(b) Define Active sensor and Passive sensor and Explain in detail for Meteorological satellites designed.

13. (a) Describe in detail with neat sketch on Key elements for Terrain Evaluation.

Or

(b) Discuss image enhancement techniques and explain image classification procedure with flow chart.

14. (a) Describe in detail, Components of GIS and Theoretical models of GIS operation.

Or

(b) Explain in detail for Spatial and Non-spatial data and write the major components of a GIS.

15. (a) What are the traditional advantages and disadvantages of raster versus vector spatial data structures?

Or

(b) What are the techniques adopted for Land use and Land Cover change detection analysis and explain in detail for Watershed?

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