UNIT I REMOTE SENSING

DEFINITION AND PROCESS OF REMOTE SENSING

INTRODUCTION

Now-a-days the field of Remote Sensing and GIS has become exciting and glamorouswith 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.

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 sense also involves the sensing of emitted energy and the use of non-imaging sensors.

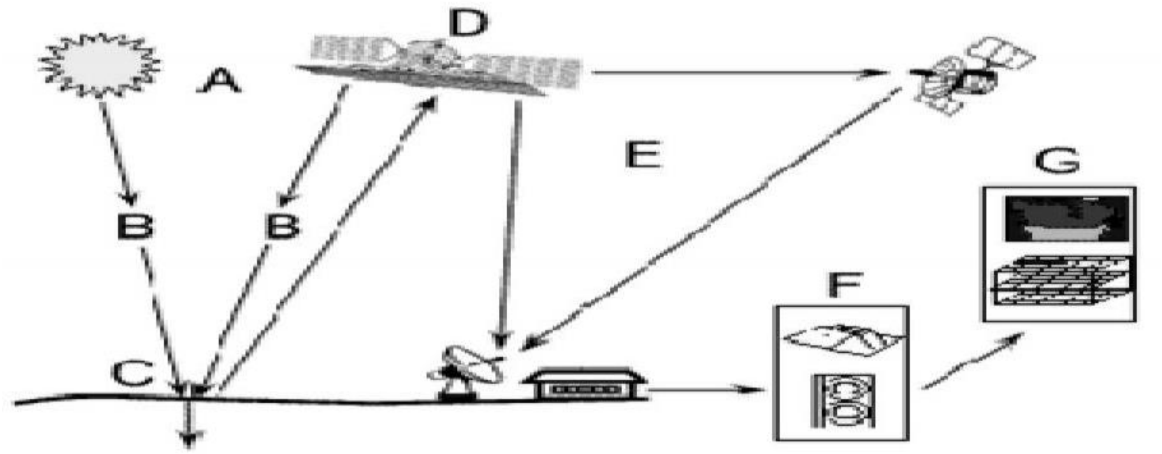


Fig 1.1- Components of Remote Sensing

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

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.

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.

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.

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).

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

Application (G) - the final element of the remote sensing process is achieved whenwe 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 balloon1903 - first plane

1909 first photo from a plane1903-4 -B/W infrared film

WW I and WW II1960 – space

Passive/ Active Remote Sensing

Depending on the source of electromagnetic energy, remote sensing can be classified as passive or active remote sensing.

In the case of passive remote sensing, source of energy is that naturally available such as the Sun. Most of the remote sensing systems work in passive mode using solar energy as the source of EMR. Solar energy reflected by the targets at specific wavelength bands are recorded using sensors on board air-borne or space borne platforms. In order to ensure ample signal strength received at the sensor, wavelength / energy bands capable of traversing through the atmosphere, without significant loss through atmospheric interactions, are generally used in remote sensing Any object which is at a temperature above 0o K (Kelvin) emits some radiation, which is approximately proportional to the fourth power of the temperature of the object. Thus the Earth also emits some radiation since its ambient temperature is about 300o K. Passive sensors can also be used to measure the Earth‘s radiance but they are not very popular as the energy content is very low.

In the case of active remote sensing, energy is generated and sent from the remote sensing platform towards the targets. The energy reflected back from the targets are recorded using sensors on board the remote sensing platform. Most of the microwave remote sensing is done through active remote sensing.

As a simple analogy, passive remote sensing is similar to taking a picture with an ordinary camera whereas active remote sensing is analogous to taking a picture with camera having built-in flash

What is Sensor Platform?

Platform is a stage where sensor or camera is mounted to acquire information about a target under investigation.

According to Lillesand and Kiefer (2000), a platform is a vehicle, from which a sensor can be operated.

For remote sensing applications, sensors should be mounted on suitable stable platforms

As the platform height increases the spatial resolution and observational area increases.

The types or characteristics of platform depend on the type of sensor to be attached and its application.

Type of Platforms:

Platforms can vary from stepladders to satellites.

There are different types of platforms and based on its altitude above earth surface.

Three types of platforms are used to mount the remote sensors

1.Ground based Platform

2. Air - borne Platform, and

3. Space-borne Platform

Ground based Platforms:

- Ground based platforms are used to record detailed information about the objects or features of the earth's surface
- These are developed for the scientific understanding on the signal-object and signal-sensor interactions.
- It includes both the laboratory and field study, used for both in designing sensors and identification and characterization of land features.
- Example: Handheld platform, cherry picker, towers, portable masts and vehicles etc.
- Portable handheld photographic cameras and spectroradiometers are largely used in laboratory and field experiments as a reference data and ground truth verification.
- Crane, Ground based platform (cherry Picker Platform extend up to approx. 15m.)

Air- borne/ based Platforms:

- Airborne platforms were the sole non-ground-based platforms for early remote sensing work.
- Aircraft remote sensing system may also be referred to as sub-orbital or airborne, or aerial remote sensing system
- At present, airplanes are the most common airborne platform.
- observation platforms include balloons, drones (short sky spy) and high altitude sounding rockets. Helicopters are occasionally used.

Balloons:

- Balloons are used for remote sensing observation (aerial photography) and nature conservation studies.
- The first aerial images were acquired with a camera carried aloft by a balloon in 1859.
- Balloon floats at a constant height of about 30 km.

- Balloons as platforms are not very expensive like aircrafts. They have a great variety of shapes, sizes and performance capabilities.
- The balloons have low acceleration, require no power and exhibit low vibrations.
- It consists of a rigid circular base plate for supporting the entire sensor system which is protected by an insulating and shock proof light casing.
- The payload used for Indian balloon experiment of three Hasselblad cameras with different film filter combinations, to provide PAN, infra red black and white and infra red false color images.
- Flight altitude being high compared to normal aircraft height used for aerial survey, balloon imagery gives larger synoptic views.
- The balloon is governed by the wind at the floating altitude
- There are three main types of balloon systems, viz. free balloons, Tethered balloons and Powered Balloons.
- Free balloons can reach almost top of the atmosphere; hence, they can provide a platform at intermediate altitude between those of aircraft and spacecraft (shown in fig.)
- Have altitude range of 22-40 km and can be used to a limited extent as a platform.

Drone:

- Drone is a miniature remotely piloted aircraft.
- It is designed to fulfill requirements for a low cost platform, with long endurance, moderate payload capacity and capability to operate without a runway or small runway.
- Drone includes equipment of photography, infrared detection, radar observation and TV surveillance. It uses satellite communication link.
- An onboard computer controls the payload and stores data from different sensors and instruments.

Aircraft Platform:

- Aircraft are used to collect very detailed images.
- Helicopters can be for pinpoint locations but it vibrates and lacks stability.
- Special aircraft with cameras and sensors on vibration less platforms are traditionally used to acquire aerial photographs and images of land surface features.
- While low altitude aerial photography results in large scale images providing detailed information on the terrain, the high altitude smaller scale images offer advantage to cover a larger study area with low spatial resolution
- Aircraft platforms offer an economical method of remote sensing data collection for

small to large study areas with cameras, electronic imagers, across- track and along-track scanners, and radar and microwave scanners.

- Low Altitude Aircraft: It is most widely used and generally operates below 30,000 ft.
- It is suitable for obtaining image data for small areas having large scale
- High altitude aircraft: It includes jet aircraft with good rate of climb, maximum speed, and high operating ceiling. It acquires imagery for large areas

Rockets as Platforms:

- High altitude sounding rocket platforms are useful in assessing the reliability of the remote sensing techniques as regards their dependence on the distance from the target is concerned.
- Balloons have a maximum altitude of approximately 37 km, while satellites cannot orbit below 120 km. High altitude sounding rockets can be used to a moderate altitude above terrain
- Synoptic imagery can be obtained from rockets for areas of some 500,000 square km.

Space-borne/ based Platforms:

- In space- borne remote sensing, sensors are mounted on-board a spacecraft (space shuttle or satellite) orbiting the earth.
- Space-borne or satellite platform are onetime cost effected but relatively lower cost per unit area of coverage, can acquire imagery of entire earth without taking permission.
- Space-borne imaging ranges from altitude 250 km to 36000 km.
- Space-borne remote sensing provides the following advantages:

Large area coverage;

- Frequent and repetitive coverage of an area of interest;
- Quantitative measurement of ground features using radiometrically calibrated sensors;
- Semi-automated computerised processing and analysis;
- Relatively lower cost per unit area of coverage.

Spacecraft as Platform:

- Remote sensing is also conducted from the space shuttle or artificial satellites. Artificial satellites are manmade objects, which revolve around another object.
- Satellite can cover much more land space than planes and can monitor areas on a regular basis.
- Later on with LANDSAT and SPOT satellites program, space photography received a higher impetus

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.

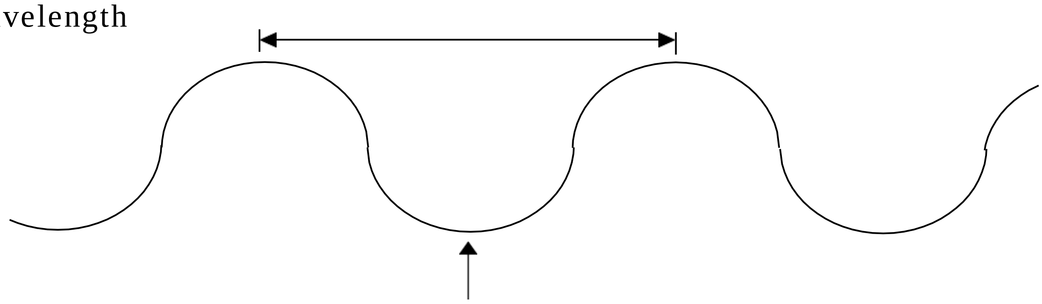
Electromagnetic radiation consists of an electrical field (E) which varies inmagnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c). Two 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 throughspace 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

Wavelength



Frequency

(how many times peakpasses per second)

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 (3×10^8 m/s)

Therefore, the two are inversely related to each other. The shorter the wavelength, thehigher 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 gammaand 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.

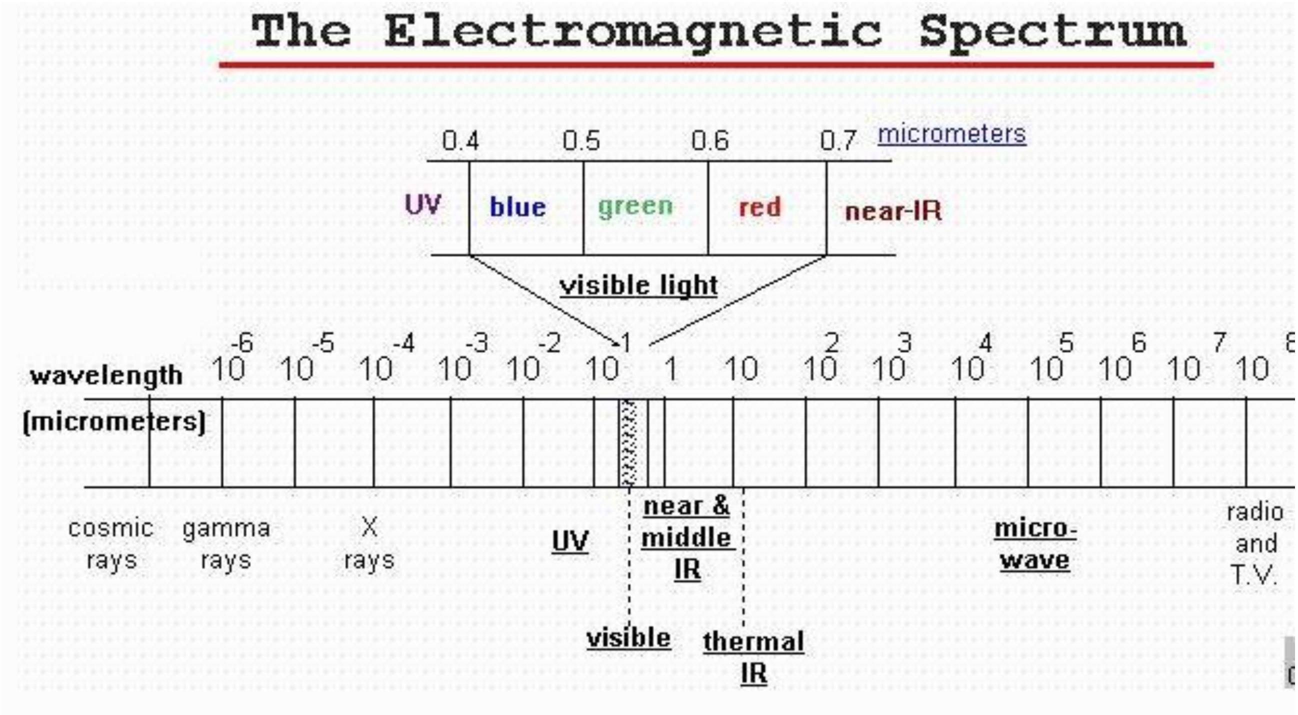


Fig 3 – Electromagnetic Spectrum

WAVELENGTH REGIONS IMPORTANT TO REMOTE SENSING:

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.

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 wavelengthis 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.

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 commonlyreferred 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 radiobroadcasts.

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.

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 thedirection of wave travel.

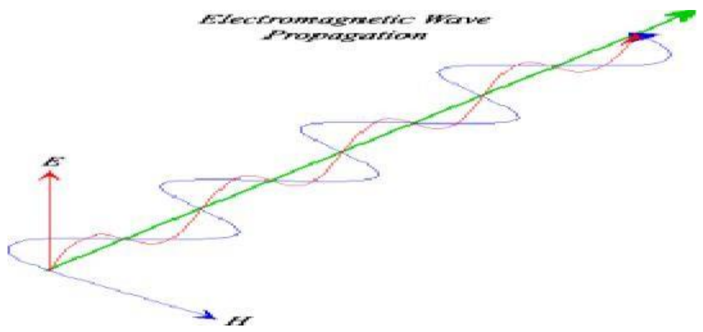


Fig 1.4 – Electromagnetic propagation

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:

$f = 1 / TT = 1 / f$

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*) - $6.63\text{x}10^{-34}$ 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.

PARTICAL THEORY

The basic idea of quantum theory is that radiant energy is transmitted inindivisiblepackets 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 notgive the intensity of energy at a point in space, but gives the probability of finding a photon atthat 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, theamount 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 ofa given material are characteristic to that material.

STEFAN–BOLTZMANN LAW

Stefan–Boltzmann law, also known as **Stefan's law**, describes the power radiated froma 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*:

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

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 $2.8977721(26)\times10^{-3}$ mK.[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 r 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 usedfor the Wien approximation.

Blackbody Radiation

A blackbody is a hypothetical, ideal radiator. It absorbs and reemits the entire energy incident upon it.

Total energy emitted by a black body varies with temperature as given in Eq. 4. The total energy is distributed over different wavelengths, which is called the spectral distribution or spectral curve here. Area under the spectral curve gives the total radiant exitance *M*.

In addition to the total energy, the spectral distribution also varies with the temperature. Fig. 4 shows the spectral distribution of the energy radiated from black bodies at different temperatures. The figure represents the Stefan-Boltzmann‘s law graphically. As the temperature increases, area under the curve, and hence the total radiant exitance increases.

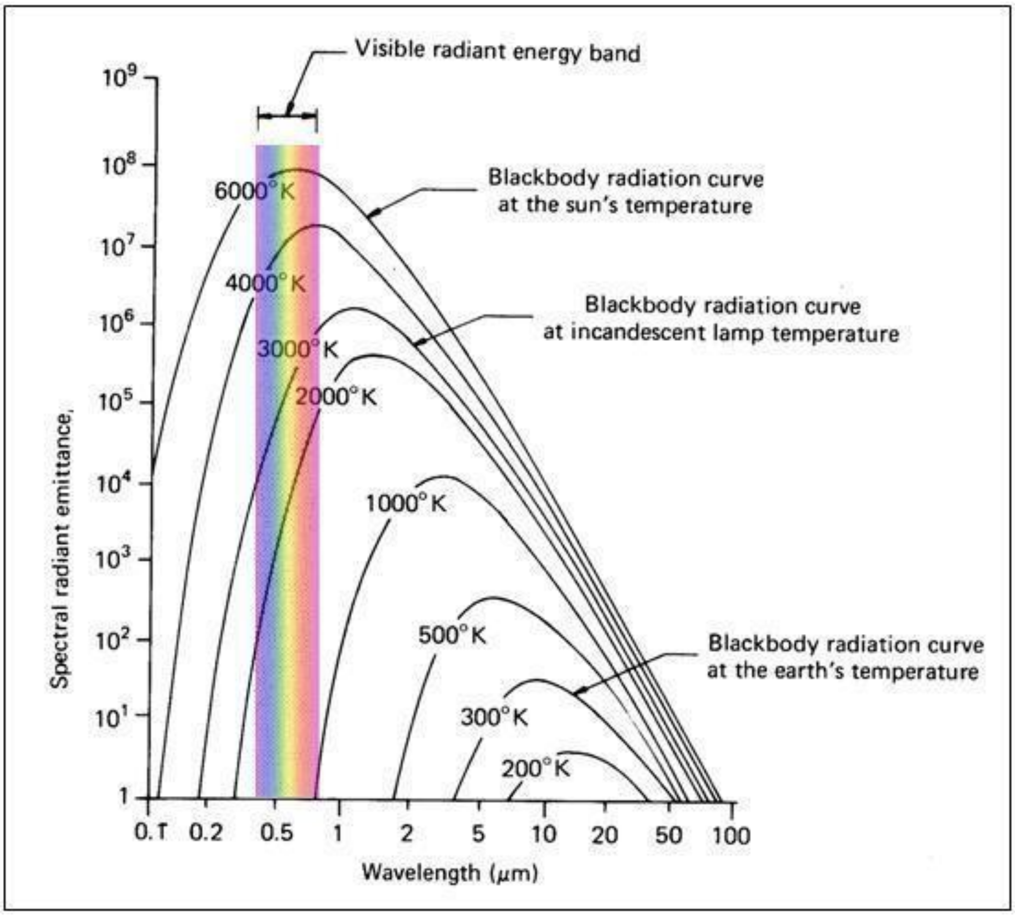


Figure5. Spectral energy distribution of blackbody at various temperatures

From Fig. 4, it can be observed that the peak of the radiant exitance varies with wavelength. As the temperature increases, the peak shifts towards the left. This is explained by the Wien's displacement law. It states that the dominant wavelength at which a black body radiates λ_m is Inversely proportional to the absolute temperature of the black body (in K) and is represented as given below.

UNIT II EMR INTERACTION WITH ATMOSPHERE AND EARTH MATERIALS

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 .

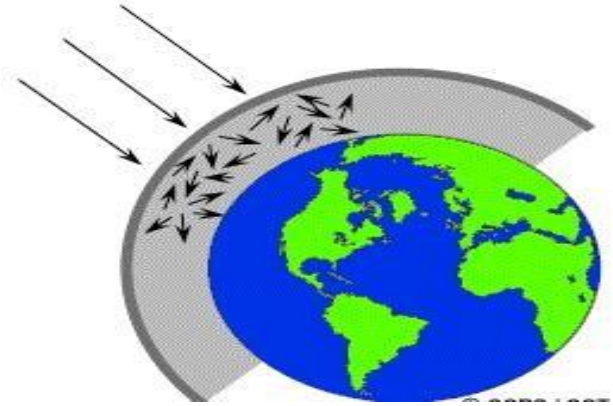


Fig 2.1 Energy Interaction with Atmosphere

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 dependson several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere. Thereare three (3) types of scattering which take place.

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 nitrogenand 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 theday 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.

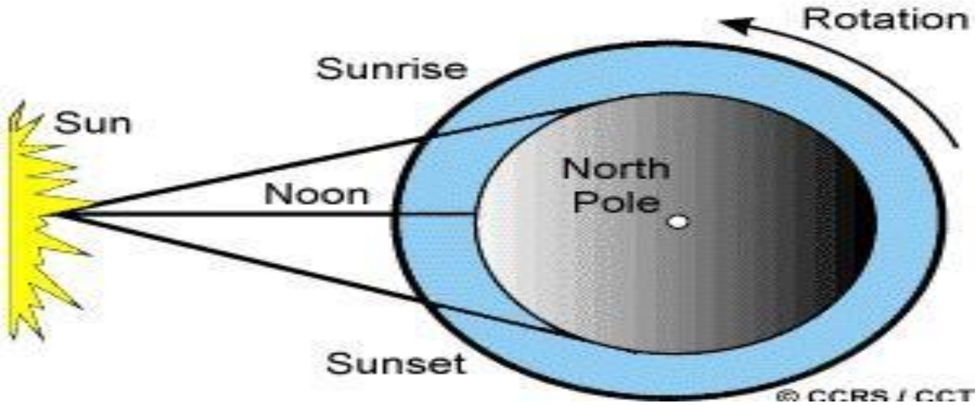


Fig2.2 . Raleigh Scattering

ABORPTION

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).

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 ofMie 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.

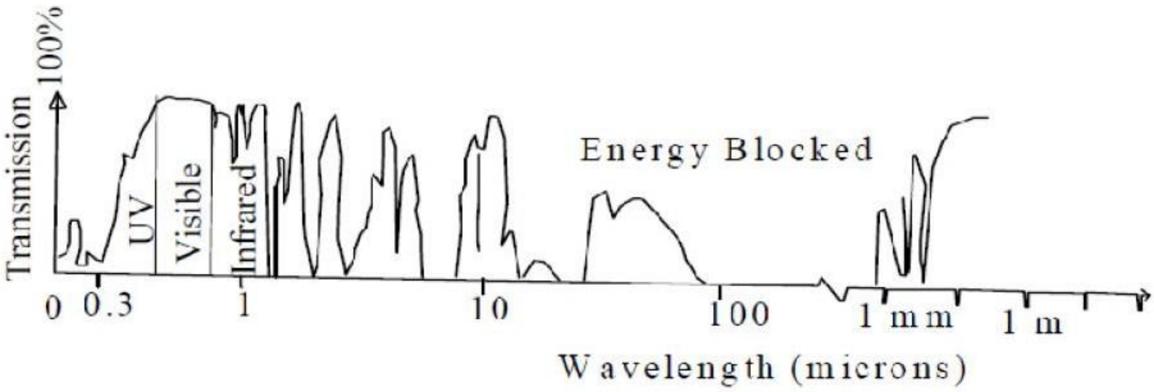
Water droplets and large dust particles can cause this type of scattering. Nonselective scattering gets its name from the fact that all wavelengths are scattered about equally. This type of scattering causes fog and clouds to appear white to our eyes because blue, green, and red light are all scattered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

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 windowsare 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



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.

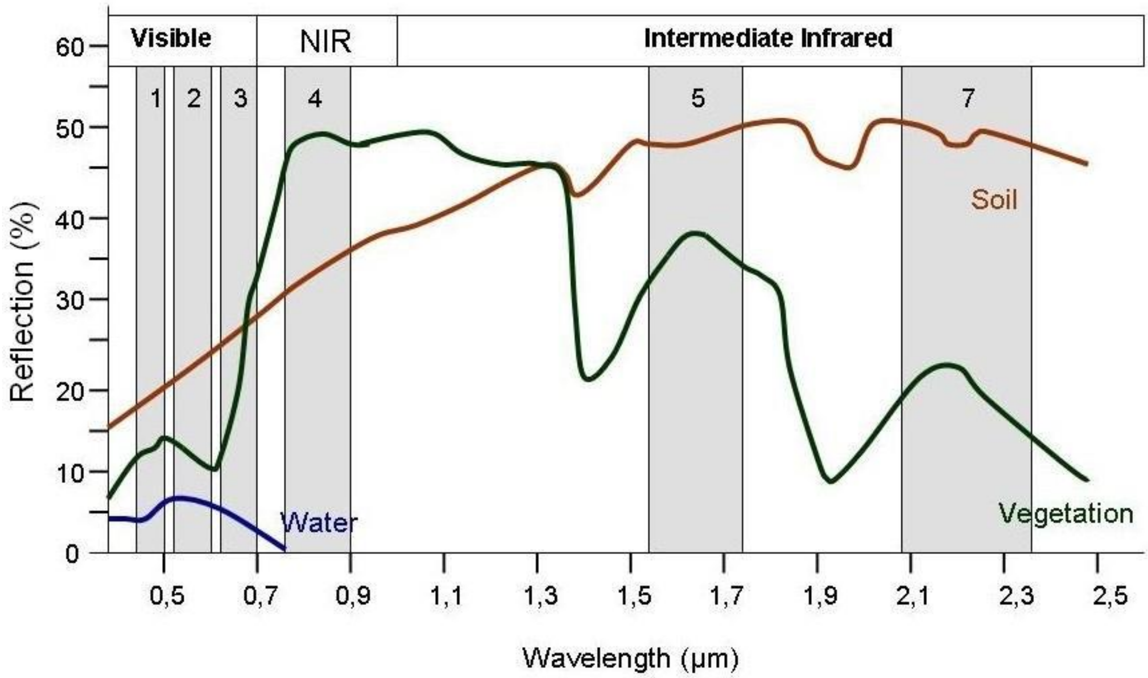


Fig 2.3 Spectral reflectance Curve

Every object on the surface of the earth has its unique spectral reflectance.Fig. 2.3 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. 2.3) 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 areused to denote the spectral response of a target.

The characteristic spectral reflectance curve Fig2.3 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.

ENERGY INTERACTIONS WITH EARTH SURFACE FEATURES

Energy incident on the Earth‘s surface is absorbed, transmitted or reflected depending on the wavelength and characteristics of the surface features (such as barren soil, vegetation, water body). Interaction of the electromagnetic radiation with the surface features is dependent on the characteristics of the incident radiation and the feature characteristics. After interaction with the surface features, energy that is reflected or re-emitted from the features is recorded at the sensors and are analysed to identify the target features, interpret the distance of the object, and /or its characteristics.

This lecture explains the interaction of the electromagnetic energy with the Earth‘s surface features.

Energy Interactions

The incident electromagnetic energy may interact with the earth surface features in three possible ways: Reflection, Absorption and Transmission. These three interactions are

Reflection Absorption Earth Transmission

Incident radiation

Reflection occurs when radiation is redirected after hitting the target. According to the law of reflection, the angle of incidence is equal to the angle of reflection the EM energy which is absorbed by the Earth‘s surface is available for emission and as thermal radiation at longer wavelengths.

Transmission occurs when radiation is allowed to pass through the target. Depending upon the characteristics of the medium, during the transmission velocity and wavelength of the radiation changes, whereas the frequency remains same. The transmitted energy may further get scattered and / or absorbed in the medium.

These three processes are not mutually exclusive. Energy incident on a surface may be partially reflected, absorbed or transmitted. Which process takes place on a surface depends on the following factors:

- Wavelength of the radiation
- Angle at which the radiation intersects the surface
- Composition and physical properties of the surface

The relationship between reflection, absorption and transmission can be expressed through the principle of conservation of energy. Let *EI* denotes the incident energy, *ER* denotes the reflected energy, *EA* denotes the absorbed energy and *ET* denotes the transmitted energy. Then the principle of conservation of energy (as a function of wavelength λ) can be expressed as

$EI(\lambda) = ER(\lambda) + EA(\lambda) + ET(\lambda)$ (1)

Since most remote sensing systems use reflected energy, the energy balance relationship can be better expressed in the form

$ER(\lambda) = EI(\lambda) - EA(\lambda) - ET(\lambda)$ (2)

The reflected energy is equal to the total energy incident on any given feature reduced by the energy absorbed or transmitted by that feature.

Reflection

Reflection is the process in which the incident energy is redirected in such a way that the angle of incidence is equal to the angle of reflection. The reflected radiation leaves the surface at the

same angle as it approached.
Scattering is a special type of reflection wherein the incident energy is diffused in many directions and is sometimes called diffuse reflection.

When electromagnetic energy is incident on the surface, it may get reflected or scattered depending upon the roughness of the surface relative to the wavelength of the incident energy. If the roughness of the surface is less than the wavelength of the radiation or the ratio of roughness to wavelength is less than 1, the radiation is reflected. When the ratio is more than 1 or if the roughness is more than the wavelength, the radiation is scattered.
Fraction of energy that is reflected / scattered is unique for each material. This will aid in distinguishing different features on an image
A feature class denotes distinguishing primitive characteristic or attribute of an image that have been classified to represent a particular land cover type/spectral signature. Within one feature class, the proportion of energy reflected, emitted or absorbed depends on the wavelength. Hence, in spectral range two features may be indistinguishable; but their reflectance properties may be different in another spectral band. In multi-spectral remote sensing, multiple sensors are used to record the reflectance from the surface features at different wavelength bands and hence to differentiate the target features.
Variations in the spectral reflectance within the visible spectrum give the colour effect to the features.
For example, blue colour is the result of more reflection of blue light. An object appears as ―green‖ when it reflects highly in the green portion of the visible spectrum. Leaves appear green since its chlorophyll pigment absorbs radiation in the red and blue wavelengths but reflects green wavelengths. Similarly, water looks blue-green or blue or green if viewed through visible band because it reflects the shorter wavelengths and absorbs the longer wavelengths in the visible band. Water also absorbs the near infrared wavelengths and hence appears darker when viewed through red or near infrared wavelengths. Human eye uses reflected energy variations in the visible spectrum to discriminate between various features.
For example, shows a part of the Krishna River Basin as seen in different bands of the Landsat ETM+ imagery. As the concepts of false colour composite (FCC) have been covered in module 4, readers are advised to refer to the material in module 4 for better understanding of the colour composite imageries as shown in Fig. 5. Reflectance of surface features such as water, vegetation and fallow lands are
different in different wavelength bands. A combination of more than one spectral band helps

to attain better differentiation of these features.

Diffuse and Specular Reflection

Energy reflection from a surface depends on the wavelength of the radiation, angle of incidence and the composition and physical properties of the surface.

Roughness of the target surface controls how the energy is reflected by the surface. Based on the roughness of the surface, reflection occurs in mainly two ways.

Specular reflection: It occurs when the surface is smooth and flat. A mirror-like or smooth reflection is obtained where complete or nearly complete incident energy is reflected in one direction. The angle of reflection is equal to the angle of incidence. Reflection from the surface is the maximum along the angle of reflection, whereas in any other direction it is negligible.

Diffuse (Lambertian) reflection: It occurs when the surface is rough. The energy is reflected uniformly in all directions. Since all the wavelengths are reflected uniformly in all directions, diffuse reflection contains spectral information on the "color" of the reflecting surface. Hence, in remote sensing diffuse reflectance properties of terrain features are measured. Since the reflection is uniform in all direction, sensors located at any direction record the same reflectance and hence it is easy to differentiate the features.

Based on the nature of reflection, surface features can be classified as specular reflectors, Lambertian reflectors. An ideal specular reflector completely reflects the incident energy with angle of reflection equal to the angle incidence. An ideal Lambertian or diffuse reflector scatters all the incident energy equally in all the directions.

The specular or diffusive characteristic of any surface is determined by the roughness of the surface in comparison to the wavelength of the incoming radiation. If the wavelengths of the incident energy are much smaller than the surface variations or the particle sizes, diffuse reflection will dominate. For example, in the relatively long wavelength radio range, rocky terrain may appear smooth to incident energy. In the visible portion of the spectrum, even a material such as fine sand appears rough while it appears fairly smooth to long wavelength microwaves.

Most surface features of the earth are neither perfectly specular nor perfectly diffuse reflectors. In near specular reflection, though the reflection is the maximum along the angle of reflection, a fraction of the energy also gets reflected in some other angles as well. In near Lambertian reflector, the reflection is not perfectly uniform in all the directions. The characteristics of different types of reflectors are

Near diffusive Near specular Ideal diffusive Ideal specular Angle of reflection Angle of incidence

Lambertian reflectors are considered ideal for remote sensing. The reflection from an ideal Lambertian surface will be the same irrespective of the location of the sensor. On the other hand, in case of an ideal specular reflector, maximum brightness will be obtained only at one location and for the other locations dark tones will be obtained from the same target. This variation in the spectral signature for the same feature affects the interpretation of the remote sensing data.

Most natural surfaces observed using remote sensing are approximately Lambertian at visible and IR wavelengths. However, water provides specular reflection. Water generally gives a dark tone in the image. However due to the specular reflection, it gives a pale tone when the sensor is located in the direction of the reflected energy.

Spectral Reflectance of Earth Surface

Vegetation

In general, healthy vegetation is a very good absorber of electromagnetic energy in the visible region. Chlorophyll strongly absorbs light at wavelengths around 0.45 (blue) and 0.67 µm (red) and reflects strongly in green light, therefore our eyes perceive healthy vegetation as green. Healthy plants have a high reflectance in the near-infrared between 0.7 and 1.3 µm. This is primarily due to healthy internal structure of plant leaves. As this internal structure varies amongst different plant species, the near infrared wavelengths can be used to discriminate between different plant species.

Water

In its liquid state, water has relatively low reflectance, with clear water having the greatest reflectance in the blue portion of the visible part of the spectrum. Water has high absorption and virtually no reflectance in near infrared wavelengths range and beyond. Turbid water has a higher reflectance in the visible region than clear water. This is also true for waters containing high chlorophyll concentrations.

Ice and Snow

Ice and snow generally have high reflectance across all visible wavelengths, hence their bright white appearance. Reflectance decreases in the near infrared portion and there is very low reflectance in the SWIR (shortwave infrared). The low reflection of ice and snow in the SWIR is related to their microscopic liquid water content. Reflectance differs for snow and ice depending on the actual composition of the material including impurities and grain size.

Soil

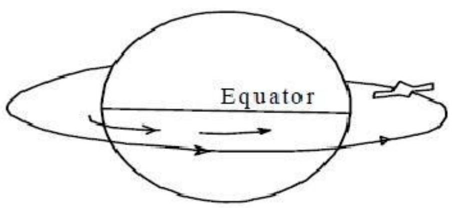
Bare soil generally has an increasing reflectance, with greater reflectance in near-infrared and shortwave infrared. Some of the factors affecting soil reflectance are:

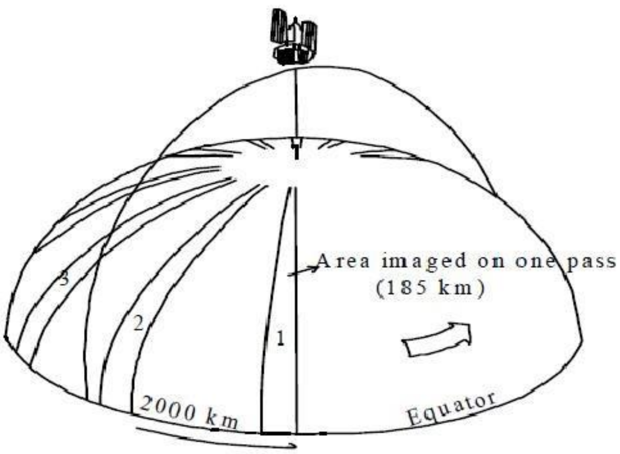
- Moisture content
- Soil texture (proportion of sand, silt, and clay)
- Surface roughness
- Presence of iron oxide
- Organic matter content

UNIT III OPTICAL AND MICROWAVE REMOTE SENSING

Remote sensing satellites use two types of orbits:

- **Geosynchronous (geostationary)** satellites orbit 36,000 km over the equator and remain over a single spot. They always view the same region, and produce the movie "loops" seen on TV news. They cannot cover the high latitudes. They are used for weather forecasting, satellite TV, and communications. These satellites are not really stationary, but appear stationary when viewed from earth because their orbit at the same rate as the earth's daily rotation.
- **Polar orbiting** satellites fly several hundred km over the earth's surface with a rotation period of about 110 minutes. They can cover most of the earth's surface except for regions immediately adjacent to the poles. They have an inclination which measures the angle at which they cross the equator and which determines how close they get to passing directly over the poles. They are also called **sun synchronous** satellites because they often try to maintain the same angle with respect to the sun and hence the illumination. The imaging satellilites want some shadows, but not too many, so they generally time their orbits for mid morning collections, which can also minimize cloud formation. These satellites have characteristic **orbital patterns**, similar to those of the space shuttle or international space station (ISS). They will make about a dozen orbits every day, and at the equator each orbit will be about 3000 km apart. Almost all satellites used for remoted sensing and GIS work are polar orbiters.





Geo – Stationery and Sun synchronous satellites

REMOTE SENSING SENSORS

Sensor is a device that gathers energy (EMR or other), converts it into a signal and presents it in a form suitable for obtaining information about the target under investigation. These may be active or passive depending on the source of energy. Sensors used for remote sensing can be broadly classified as those operating in Optical-Infrared (OIR) region and those operating in the microwave region. OIR and microwave sensors can further be subdivided into passive and active. Active sensors use their own source of energy. Earth surface is illuminated through energy emitted by its own source, a part of it is reflected by the surface in the direction of the sensor, which is received to gather the information. Passive sensors receive solar electromagnetic energy reflected from the surface or energy emitted by the surface itself. These sensors do not have their own source of energy and can not be used at nighttime, except thermal sensors. Again, sensors (active or passive) could either be imaging, like camera or sensor, which acquire images of the area and non-imaging types like non-scanning radiometer or atmospheric sounders.

Resolution

Resolution is defined as the ability of the system to render the information at the smallest discretely separable quantity in terms of distance (spatial), wavelength band of EMR (spectral), time (temporal) and/or radiation quantity (radiometric).

Spatial Resolution

Spatial resolution is the projection of a detector element or a slit onto the ground. In other words, scanner's spatial resolution is the ground segment sensed at any instant. It is also called ground resolution element (GRE). The spatial resolution at which data are acquired has two effects – the ability to identify various features and quantify their extent. The former one relates to the classification accuracy and the later to the ability to accurately make mensuration. Images where only large features are visible are said to have coarse or low resolution. In fine resolution images, small objects can be detected.

Spectral Resolution

Spectral emissivity curves characterize the reflectance and/or emittance of a feature or target over a variety of wavelengths. Different classes of features and details in an image can be distinguished by comparing their responses over distinct wavelength ranges. Broad classes such as water and vegetation can be separated using broad wavelength ranges (VIS, NIR), whereas specific classes like rock types would require a comparison of fine wavelength ranges to separate them. Hence spectral resolution describes the ability of the sensor to define fine wavelength intervals i.e. sampling the spatially segmented image in different spectral intervals, thereby allowing the spectral irradiance of the image to be determined.

Radiometric Resolution

This is a measure of the sensor to differentiate the smallest change in the spectral reflectance/emittance between various targets. The radiometric resolution depends on the saturation radiance and the number of quantisation levels. Thus, a sensor whose saturation is set at 100% reflectance with an 8 bit resolution will have a poor radiometric sensitivity compared to a sensor whose saturation radiance is set at 20% reflectance and 7 bit digitization.

Temporal Resolution

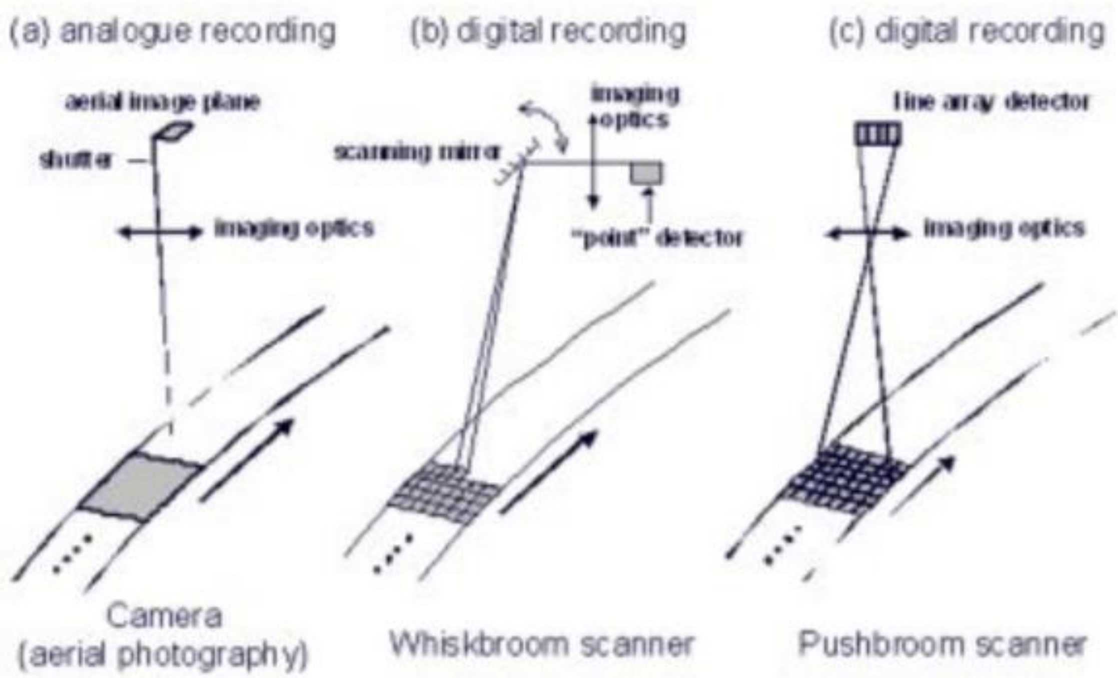
Obtaining spatial and spectral data at certain time intervals. Temporal resolution is also called as the repetivity of the satellite; it is the capability of the satellite to image the exact same area at the same viewing angle at different periods of time. The temporal resolution of a sensor depends on a variety of factors, including the satellite/sensor capabilities, the swath overlap and latitude.

Multispectral Scanning

Principle Cameras and their use for aerial photography are the simplest and oldest of sensors used for remote sensing of the Earth's surface. Cameras are framing systems (Figure 5a), which acquire a near-instantaneous "snapshot" of an area of the Earth's surface. Camera systems are passive optical sensors that use a lens (or system of lenses collectively referred to as the optics) to form an image at the focal plane, the "aerial image plane" at which an image is sharply defined.

Many electronic (as opposed to photographic) remote sensors acquire data using scanning systems, which employ a sensor with a narrow field of view that sweeps over the terrain to build up and produce a two-dimensional image of the surface. Scanning systems can be used on both aircraft and satellite platforms and have essentially the same operating principles. A scanning system used to collect data over a variety of different wavelength ranges is called a multispectral scanner (MSS), and is the most commonly used scanning system. There are two main modes or methods of scanning employed to acquire multispectral image data - across-track scanning, and along-track scanning.

Across-track scanners scan the Earth in a series of lines (Figure 5b). The lines are oriented perpendicular to the direction of motion of the sensor platform (i.e. across the swath). Each line is scanned from one side of the sensor to the other, using a rotating mirror. As the platform moves forward over the Earth, successive scans build up a two-dimensional image of the Earth’s surface. So, the Earth is scanned point by point and line after line. These systems are referred to as whiskbroom scanners. The incoming reflected or emitted radiation is separated into several spectral components that are detected independently. A bank of internal detectors, each sensitive to a specific range of wavelengths, 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.



Along-track scanners also use the forward motion of the platform to record successive scan lines and build up a two-dimensional image, perpendicular to the flight direction (Figure 5c). However, instead of a scanning mirror, they use a linear array of detectors (so-called charge-coupled devices, CCDs) located at the focal plane of the image formed by lens systems, which are “pushed” along in the flight track direction (i.e. along track). These systems are also referred to as push broom scanners, as the motion of the detector array is analogous to a broom being pushed along a floor. A separate linear array is required to measure each spectral band or channel. For each scan line, the energy detected by each detector of each linear array is sampled electronically and digitally recorded.

Regardless of whether the scanning system used is either of these two types, it has several advantages over photographic systems. The spectral range of photographic systems is restricted to the visible and near-infrared regions while MSS systems can extend this range into the thermal infrared. They are also capable of much higher spectral resolution than photographic systems. Multiband or multispectral photographic systems use separate lens systems to acquire each spectral band. This may cause problems in ensuring that the different bands are comparable both spatially and radiometrically and with registration of the multiple images. MSS systems acquire all spectral bands simultaneously through the same optical system to alleviate these problems. Photographic systems record the energy detected by means of a photochemical process which is difficult to measure and to make consistent. Because MSS data are recorded electronically, it is easier to determine the specific amount of energy measured, and they can record over a greater range of values in a digital format. Photographic systems require a continuous supply of film and processing on the ground after the photos have been taken. The digital recording in MSS systems facilitates transmission of data to receiving stations on the ground and immediate processing of data in a computer environment.

Thermal Scanner

Many multispectral (MSS) systems sense radiation in the thermal infrared as well as the visible and reflected infrared portions of the spectrum. However, remote sensing of energy emitted from the Earth’s surface in the thermal infrared (3 μm to 15 μm) is different from the sensing of reflected energy. Thermal sensors use photo detectors sensitive to the direct contact of photons on their surface, to detect emitted thermal radiation. The detectors are cooled to temperatures close to absolute zero in order to limit their own thermal emissions. Thermal sensors essentially measure the surface temperature and thermal properties of targets.

Thermal Imagers are typically across-track scanners that detect emitted radiation in only the thermal portion of the spectrum. Thermal sensors employ one or more internal temperature references for comparison with the detected radiation, so they can be related to absolute radiant temperature. The data are generally recorded on film and/or magnetic tape and the temperature resolution of current sensors can reach 0.1 °C. For analysis, an image of relative radiant temperatures is depicted in grey levels, with warmer temperatures shown in light tones, and cooler temperatures in dark tones

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)

INDIAN REMOTE SENSING SATELLITE (IRS)

The IRS mission envisages the planning and implementation of a satellite basedremotesensing 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-1C 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 ofthe 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

METEROLOGICAL SATELLITES:

Meteorological satellites designed specifically to assist. in weather predictionandmonitoring, 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.

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, regionalsoil 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.

Details of NOAA Satellite and AVHRR SensorCharacteristics 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.

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

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 coastalwaters.

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.

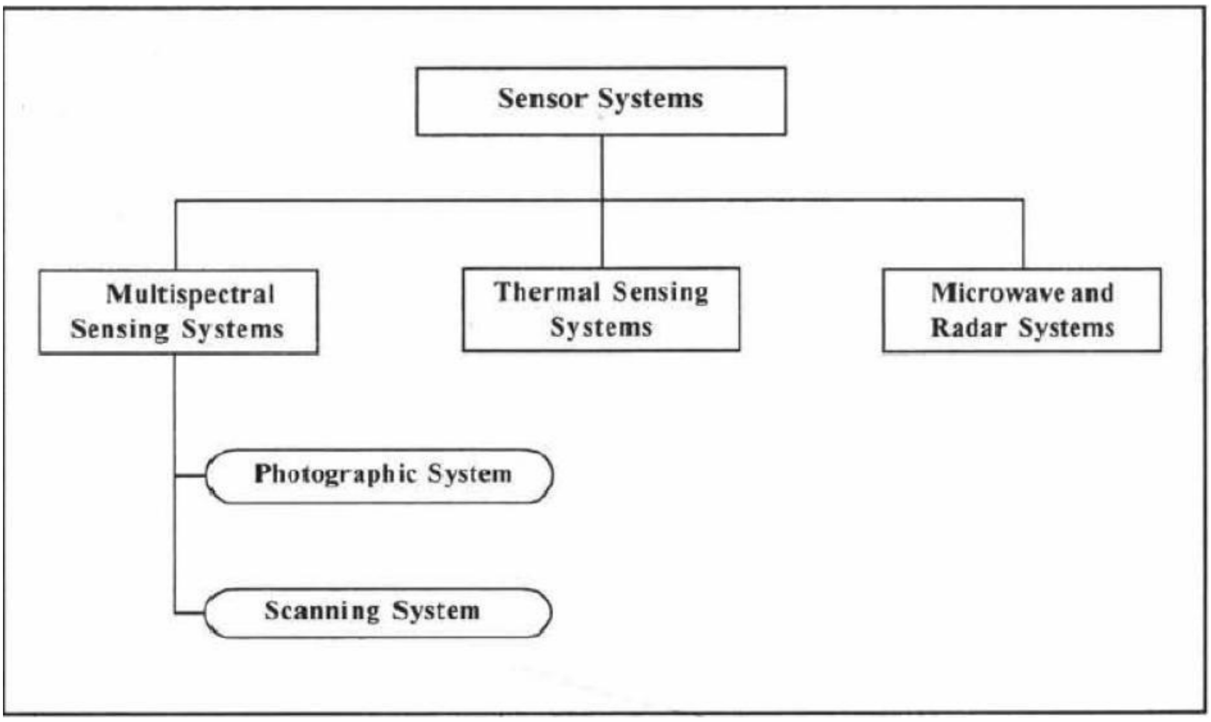


Fig 2.4 Sensor System

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 sideof 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**.**

THERMAL SENSING SYSTEMS

Thermal scanner is one of the most important thermal sensing systems, particular kindof across track multispectral scanner which senses in the thermal portion of theelectromagnetic 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.

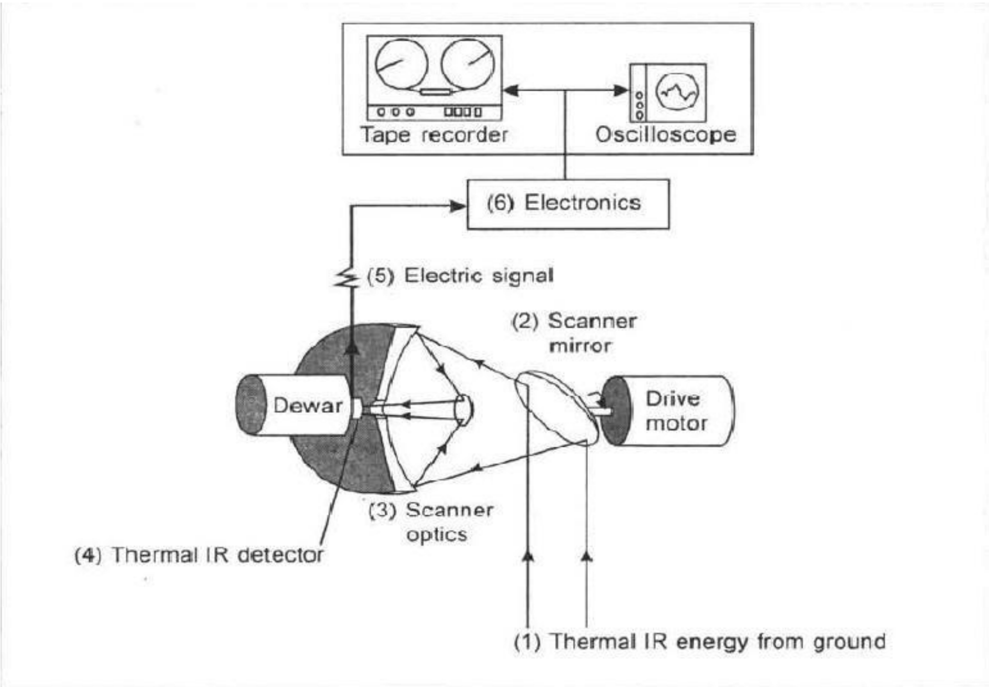


Fig 2.5 thermal Sensing System

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.

UNIT IV GEOGRAPHIC INFORMATION SYSTEM

INTRODUCTION:

The expansion of GIS is Geographic Information System which consists of three words, viz. Geographic, Information and System. Here the word‘ Geographic’ deals with spatial objectsor features which can be reference do related to a specific location on the earth surface. The object may be physical/natural or may be cultural/manmade. Likewise the word ‘Information’ dealswith the large volume of data about a particular objection the earth surface. The data includes a set of qualitative and quantitative aspects which there alworld objects acquire.

The term ‘System’ is used to represent systems approach where the complex environment (consists of a large number, of objects/features on the earth surface and their complex characteristics) is broken down in to their component parts for easy understanding and handling, but is considered to form anintegratedwholeformanagingand decisionmaking. 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,dataanalysisanddatapresentationespecially 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.

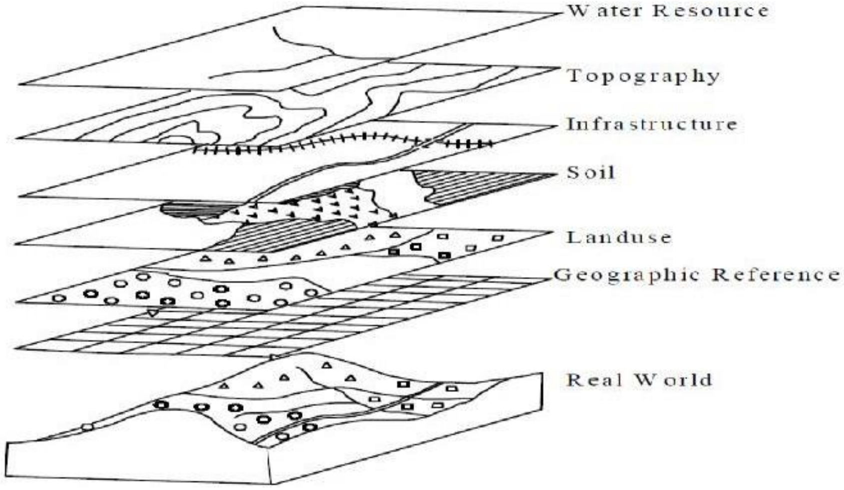


Fig 4.1 Layers

Burrough (1986) defined GIS as a set of tools for collecting, storing, retrieving a twill, transforming and displaying spatial data from the real world for a particular set of purpose. Arnoff(1989) defined GIS as a computer based system that provides four sets of capabilities tohandle georeferenced data, viz. data input, data management (data storage and retrieval), manipulation analysis and data output.

From the above definitions, we can conclude that a GIS user expects support from the system to enter geo referenced data to analyse it in various ways and to produce output (maps andother) from the data. GIS draws on concepts and ideas from many different disciplines, such as cartography, cognitive science, computer science, engineering, environmental sciences, geodesy, landscape architecture, law,photogrammetry, public policy, remote sensing, statistics and surveying.So, it involves not only the study of the fundamental issues arising from the creation, handling, storage and use of geographic information, but it also examines the impacts of GISon individuals and society and the influences of society on GIS.

DEVELOPMENT OF GIS

Keepinglongtraditionofmapmakingasbackground,G.I.S. hasbeendevelopedduringmid20th 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 wascalled 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 systemsuch 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.Sincethenanumberoforganisations anduniversitieshavebeendoingresearchinthefieldofG.I.S.anddeveloping userfriendly softwares . Now there is a growingnumberoffree,opensourceG.I.S.packages whichrun in a wide range of operating systems and performspecific tasks.

4.1.1 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.

4.1.2 COMPUTER SYSTEM

It includes both hardware and software. GIS runs through computer system ranging from portablepersonalcomputers(PCs)tomulti-usersupercomputerswhichareprogrammedby wide variety of software languages. In all ranges, there are a number things, that are essential for effective GIS operation. These include:1) a processor with sufficient power to run the software, 2)sufficient memory for the storage of large volumeofdata,3) a good quality, high resolution 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 advantagesand disadvantages. Even those lists are tool onto be mentioned here, the importan to ensure different versions of ARC View, ARC Info, Map Info., ARC GIS, Auto Cad Map etc.

Functions of GIS

General-purpose GIS software performs six major tasks such as input, manipulation, management, query and analysis, Visualization.

Input

The important input data for any GIS is digitized maps, images, spatial data and tabular data. The tabular data is generally typed on a computer using relational database management system software. Before geographic data can be used in a GIS it must be converted into a suitable digital format. The DBMS system can generate various objects such as index generation on data items, to speed up the information retrieval by a query. Maps can be digitized using a vector format in which the actual map points, lines, and polygons are stored as coordinates. Data can also be input in a raster format in which data elements are stored as cells in a grid structure.

The process of converting data from paper maps into computer files is called digitizing. Modern GIS technology has the capability to automate this process fully for large projects; smaller jobs may require some manual digitizing. The digitizing process is labour intensive and time-consuming, so it is better to use the data that already exist. Today many types of geographic data already exist in GIS-compatible formats. These
data can be obtained from data suppliers and loaded directly into a GIS.

Manipulation

GIS can store, maintain, distribute and update spatial data associated text data. The spatial data must be referenced to a geographic coordinate systems (latitude/longitude). The tabular data associated with spatial data can be manipulated with help of data base management software. It is likely that data types required for a particular GIS project will need to be transformed or manipulated in some way to make
them compatible with the system. For example, geographic information is available at different scales (scale of 1:100,000; 1:10,000; and 1:50,000). Before these can be overlaid and integrated they must be transformed to the same scale. This could be a temporary transformation for display purposes or a permanent one required for analysis. And, there are many other types of data manipulation that are routinely performed in GIS. These include projection changes, data aggregation, generalization and weeding out unnecessary data.

Management

For small GIS projects it may be sufficient to store geographic information as computer files. However, when data volumes become large and the number of users of the data becomes more than a few, it is advised to use a database management system (DBMS) to help store, organize, and manage data. A DBMS is a database management software package to manage the integrated collection of database objects such as tables, indexes, query, and other procedures in a database.

There are many different models of DBMS, but for GIS use, the relational model database management systems will be highly helpful. In the relational model, data are stored conceptually as a collection of tables and each table will have the data attributes related to a common entity. Common fields in different tables are used to link them together with relations. Because of its simple architecture, the relational DBMS software has been used so widely. These are flexible in nature and have been very wide
deployed in applications both within and without GIS.

Query

The stored information either spatial data or associated tabular data can be retrieved with the help of Structured Query Language (SQL). Depending on the type of user interface, data can be queried using the SQL or a menu driven system can be used to retrieve map data. For example, you can begin to ask questions such as:

• Where are all the soils are suitable for sunflower crop?

• What is the dominant soil type for Paddy?

• What is the groundwater available position in a village/block/district?

Both simple and sophisticated queries utilizing more than one data layer can provide timely information to officers, analysts to have overall knowledge about situation and can take a more informed decision.

Analysis

GIS systems really come into their own when they are used to analyze geographic data. The processes of geographic analysis often called spatial analysis or geo-processing uses the geographic properties of features to look for patterns and trends, and to undertake "what if" scenarios. Modern GIS have many powerful analytical tools to analyse the data. The following are some of the analysis which are generally
performed on geographic data.

A. Overlay Analysis

The integration of different data layers involves a process called overlay. At its simplest, this could be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data on soils, slope, and vegetation, or land ownership. For example, data layers for soil and land use can be combined resulting in a new map which contains both soil and land use information. This will be helpful to understand the different behaviour of the situation
on different parameters.

Proximity Analysis

GIS software can also support buffer generation that involves the creation of new polygons from points, lines, and polygon features stored in the database. For example, to know answer to questions like; How much area covered within 1 km of water canal? What is area covered under different crops? And, for watershed projects, where is the boundary or delineation of watershed, slope, water channels, different
types water harvesting structures are required, etc.

Visualization

GIS can provide hardcopy maps, statistical summaries, modeling solutions and graphical display of maps for both spatial and tabular data. For many types of geographic operation the end result is best visualized as a map or graph. Maps are very efficient at storing and communicating geographic information. GIS provides new and exciting tools to extend the art of visualization of output information to the users.

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 fornavigation 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.

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.

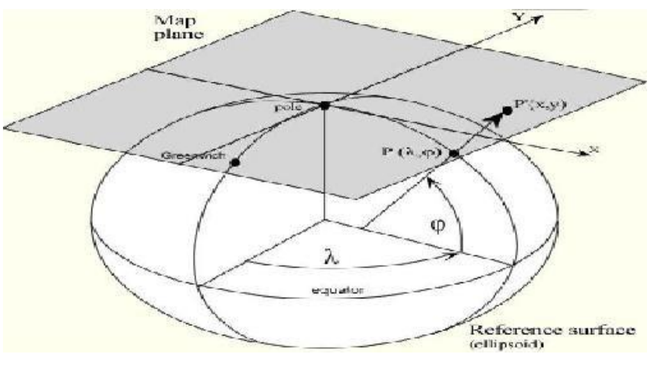


Fig 4.2 Map projections

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

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.

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.

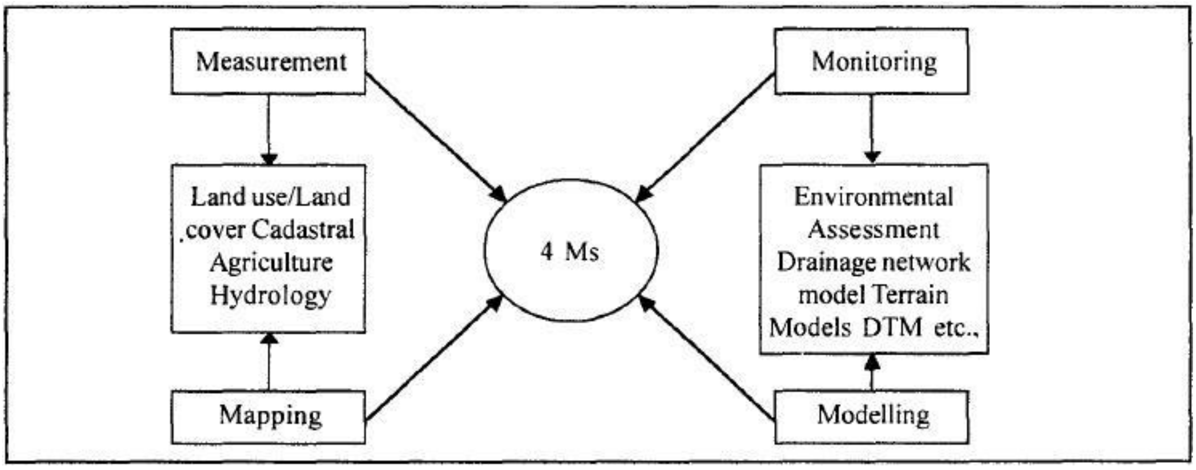


Fig 4.3 Map Analysis

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 powerfultechnology. 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.

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.

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 thedistribution 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 recordedand 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 geographicdata 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. TheCGIS 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 begunin 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.

BASIC COMPONENTS OF GIS

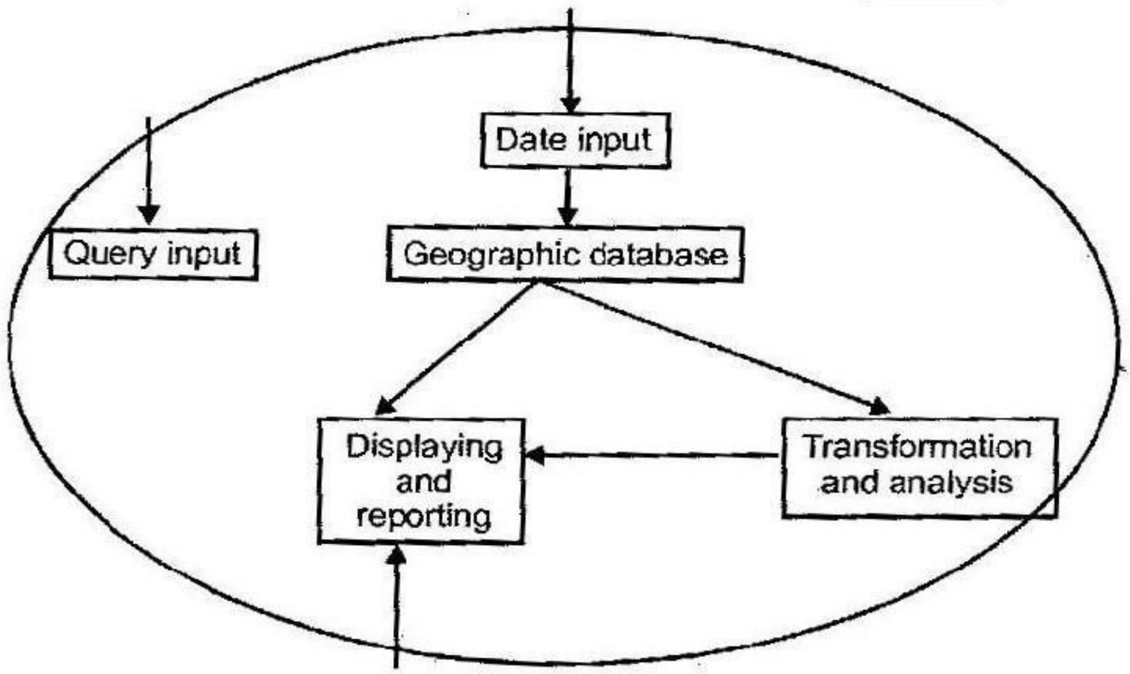


Fig 4.4 Components of GIS

Geographic information systems have three important components they are

(i) Computer hardware

(ii) Set of application software modules.

(iii) And a proper organizational contest.

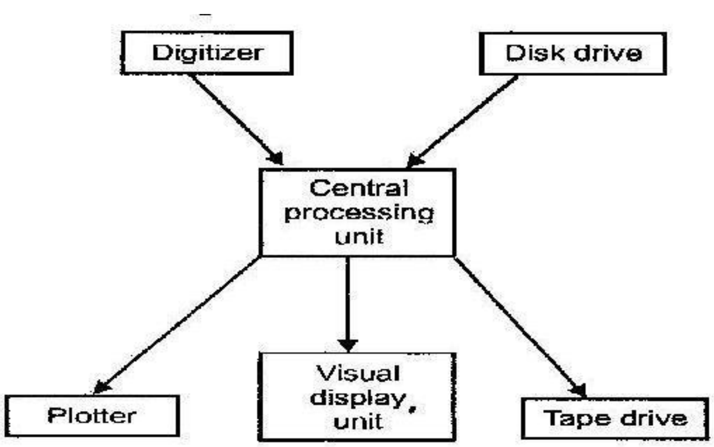


Fig 4.5 Components of GIS

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.

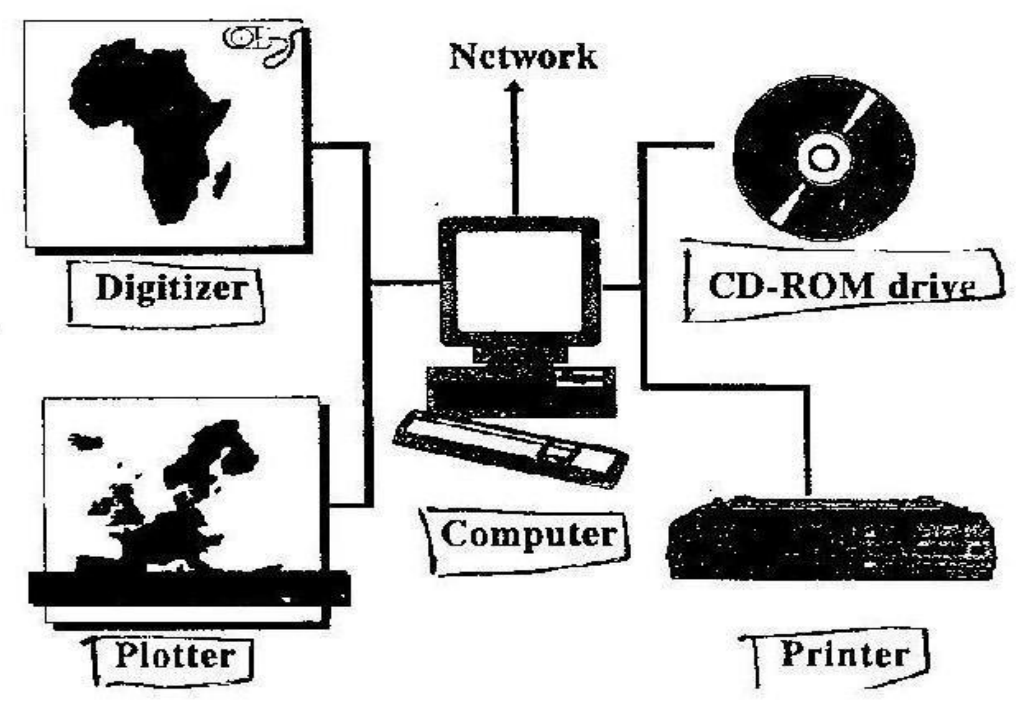


Fig 4.6 Hardware components of GIS

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 aflat file format. ARCVIEW module is a desktop mapping package oriented towards viewingand 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.

DATA TYPES

SPATIAL DATA

Spatial data (mapable data) of geo-referenced data is commonly characterized bythe 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 (latitudeand longitude etc).

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.

DBMS (DATA BASE MANAGEMENT SYSTEMS)

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

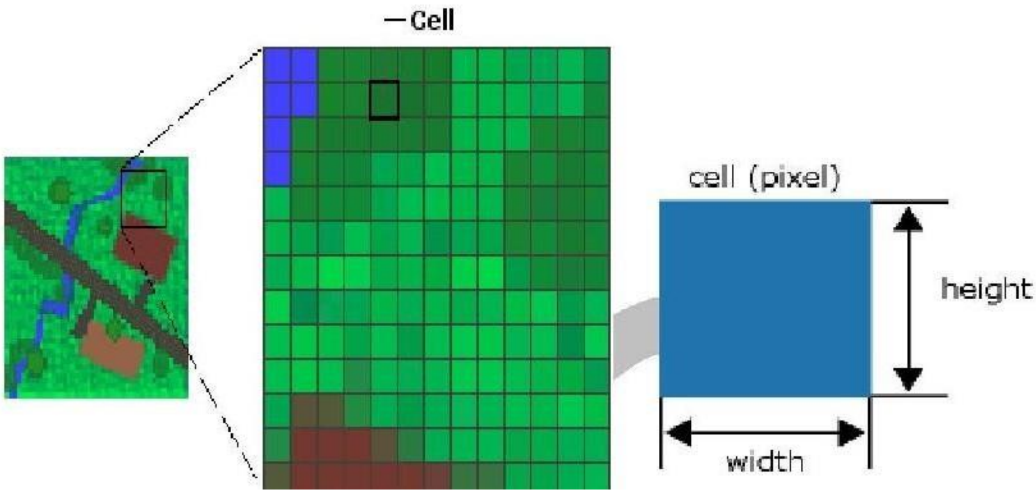


Fig 4.6 DBMS

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 isowned 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 treestructure Data base - composed of database records

Data base description - how data base records are defined; set of assembly-languagemacro instructions

Root - first segment

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

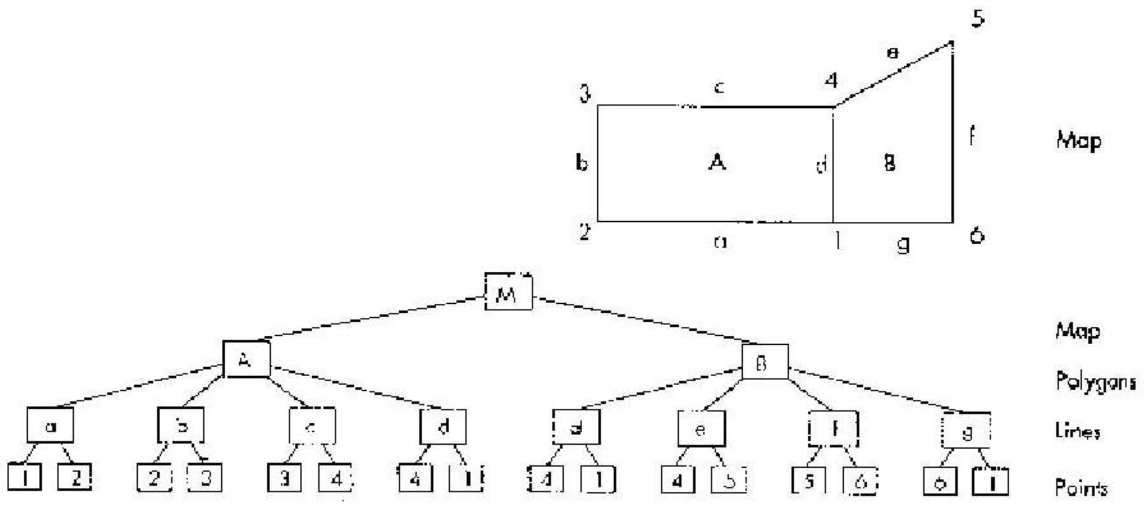


Fig 4.7 Hierarchical Data Case

NETWORK MODEL

A **network model** database management system has a more flexible structure than thehierarchical model or relational model, but pays for it in processing time and specialization oftypes. 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 numberof similar simple processing units, analogous to neurons in the human brain, 'learn' the differences and similarities between a number of inputs.

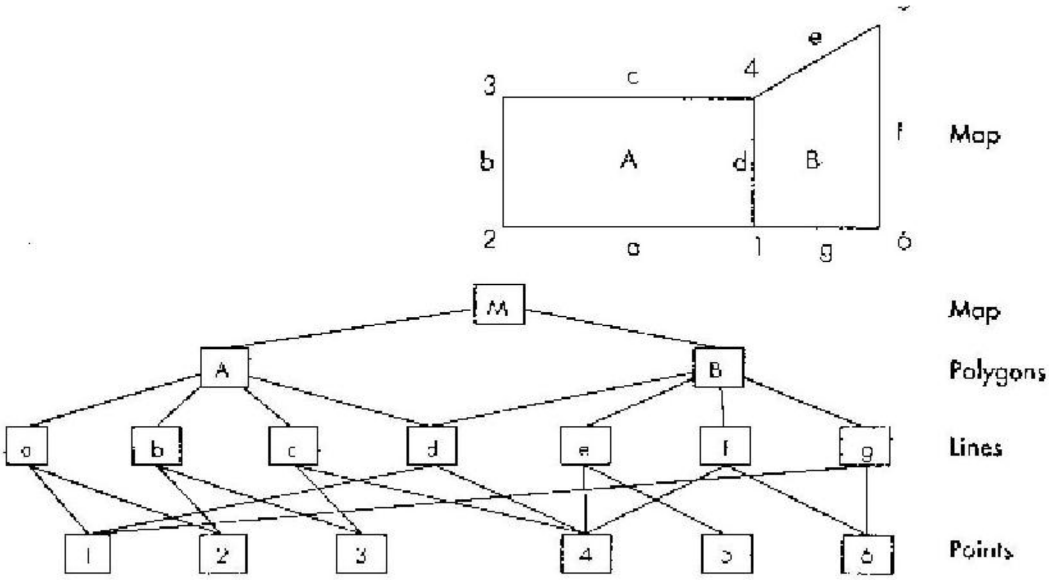


Fig 4.8 Network model

Relational data bases

In a relational data base, data is stored in tables where rows represent the objects or entities andcolumns 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:

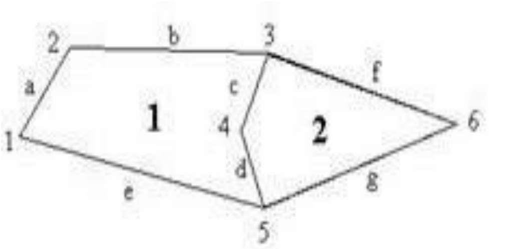
The design is based in a methodology with heavy theoretical basis, whichoffers confidence in its capacity to evolve.
It is very easy to implement it, specially in comparison with other models such ashierarchical, network, and object oriented

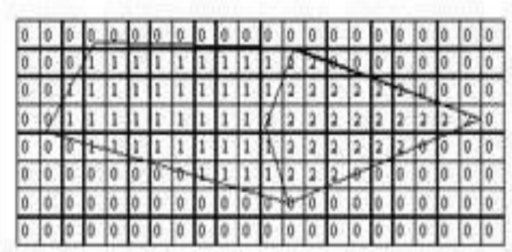
It is very flexible. New tables can be appended easily.

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

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 alsothe 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

0 No data
1 Coniferous Forest
2 Mixed

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 finda record.

2). Ordered Sequential Files

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

Only *LOG2(n+1)* searching operations are required to find a record from the file ifdivide-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 fileby selecting key features that can be searched for

Direct
index file
Inverted
index files

UNIT V MISCELLANEOUS TOPICS

IMAGE INTERPRETATION AND ANALYSIS

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:

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.

PICTORIAL DATA PRODUCTS

The pictorial data products give information of objects on the earth surface in theform 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 andwhite 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.

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

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 hasfollowing 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) Visualinterpretation poses serious limitation when we want to combine data from various sources.

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, imageenhancement 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 andgeometric 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 contrastimprovement. 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 theimage 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.

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, whetherwe 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 ultimatelyrecognizable pattern. Orchards with evenly spaced trees and urban streets with regularlyspaced 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.

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 forthin 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 thefracture or condition found on the image under study.

Elimination Key

An elimination key is arranged so that interpretation process step by step from generalto 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.

DIGITAL IMAGE PROCESSING

Introduction

As seen in the earlier chapters, remote sensing data can be analysed using visualimage 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 andanalyse 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

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

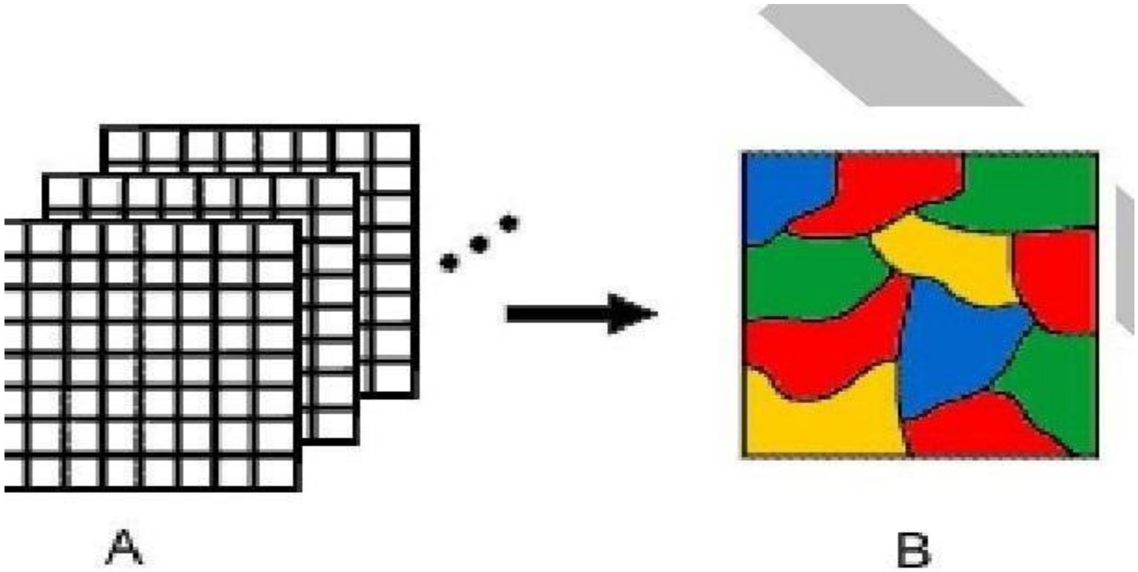


Image classification and analysis operations are used to digitally identify and classify pixelsin the data. **Classification** is usually performed on multi-channel data sets (A) and this process assigns each pixel in an image to a particular class or theme (B) based on statistical characteristics of 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 thefollowing 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.

IMAGE ENHANCEMENT TECHNIQUES

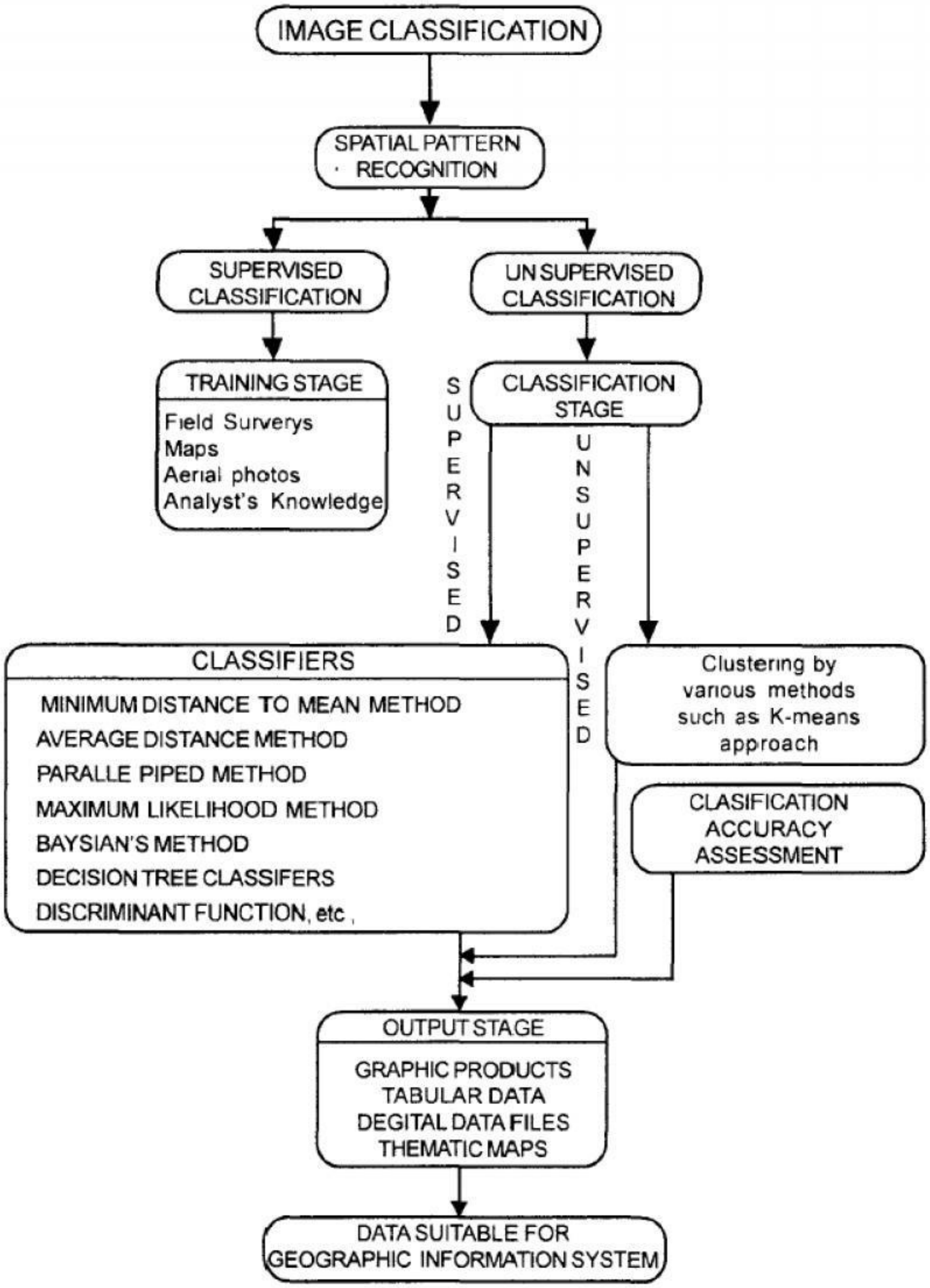
Low sensitivity of the detectors, weak signal of the objects present on the earth surface, similar reflectance of different objects and environmental conditions at the time of recording are the major causes of low contrast of the image. Another problem that complicates photographic display of digital 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 inputdata 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 ofthe analyst, although the enhanced product may have a fraction of the total information storedin 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.

IMAGE CLASSIFICATION

Image classification is a procedure to automatically categorize all pixels in an imageof 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 chosenfeatures for the individual to be classified. The classification process may therefore be considered a formof 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.



SUPERVISED CLASSIFICATION

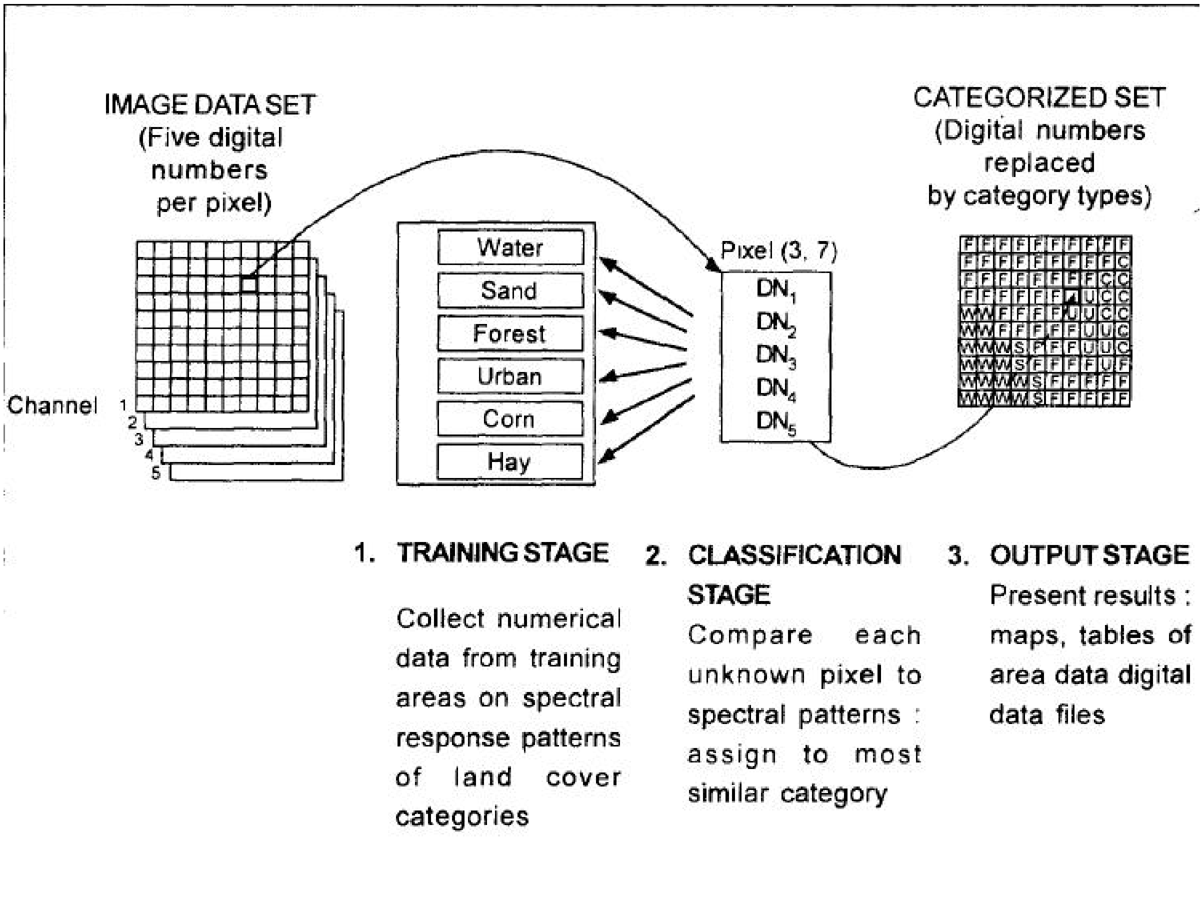
A supervised classification algorithm requires a *training sample* for each class, that is, a collection of data points known to have come from the class of interest. Theclassification is thus based on how "close" a point to be classified is to each training sample. We shall not attempt to define the 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 basicsteps (Fig. 6.23) involved in a typical supervised classification procedure are as follows:

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.

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'.

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 classificationbecomesinput for GIS for spatial analysis of the terrain.



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 thenotion 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 informationclasses, 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.

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